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USSR: Development of the Gas Industry

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USSR: Development of the Gas Industry

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Key Judgments

Soviet natural gas production will continue to grow rapidly and to provide the USSR with a growing source of energy for domestic use or export through the 1980s.

- Soviet natural gas reserves of 28 trillion cubic meters (cu m) are possibly the world's largest and would provide more than 80 years output at the 1977 production level of 346 billion cu m per year.
- Gas extraction grew from 12 billion cu m in 1956 to 346 billion cu m in 1977, an impressive average annual rate of 17 percent, and should continue to grow at about 6 percent a year into the 1980s, reaching 415 billion to 420 billion cu m in 1980, 560 billion to 600 billion cu m in 1985, and possibly more than 700 billion cu m by 1990.
- The Soviet gas trunkline system now extends well over 100,000 kilometers (km), linking major gasfields in West Siberia and Central Asia with Soviet and European consumers. Although the Soviets do not yet possess a gas distribution system capable of satisfying all consumer needs year-round, they have made some progess in that direction.
- Natural gas will become an increasingly important hard currency earner for the Soviets in trade with the West. It already is a major factor in the Soviets' position as chief energy supplier to Eastern Europe.
- Gas will contribute more than any other fuel to increments in total Soviet energy production between now and 1990. By 1990 it could constitute the largest single source of domestically produced energy.

Development of the Soviet gas industry through the 1980s will focus on West Siberia.

- Gas production at older fields in the European USSR has begun to decline fairly steeply and growth in Central Asia has slowed.

- West Siberia's northern Tyumen' Oblast holds over two-thirds of Soviet gas reserves, and new discoveries are continuing to add to the region's reserves.
- Present Soviet plans call for West Siberian gas production to increase from 68 billion cu m in 1977 to more than 150 billion cu m in 1980.
- The region will account for up to 80 percent of all additions to Soviet gas production during 1976-80 and will provide virtually all increases in output in the 1980s.

Several persistent problems will confront the Soviet gas industry in the next decade, restraining growth in output and raising costs of gas extraction and transport.

- Pipeline capacity has continually lagged behind drilling and has caused the gas industry to fail to fulfill annual and five-year plans. It probably will be responsible for below-plan production in 1980.
- Inadequate compressor power is a principal bottleneck in expansion of pipeline capacity and will remain so at least through 1980. Constructing pipelines in permafrost has also required increased time plus greater investment—particularly in Western large-diameter pipe—and the costs of gas transport are rising substantially.
- Gas extraction costs, already rising faster than those of any other Soviet energy industry, will continue to grow markedly. Increasing well depths—particularly in older producing regions—are a major cause, as are the high costs of gasfield development in the Siberian arctic.
- West Siberia's northern Tyumen' Oblast will become the source of most of the gas industry's future problems as well as the base for production growth. Inadequate infrastructure and technical difficulties posed by drilling, pipe-laying, and pipeline operation in the severe climate probably will limit the development pace.
- The older fields in the European USSR and Central Asia will become an increasing drag on national gas production, absorbing a continued high level of investment while output stagnates or declines.
- Soviet shortcomings in production of large-diameter gas pipe, compressor stations, and exploration, drilling, gas processing, and other equipment will lead to continued Soviet dependence on imports from the West.

Natural gas will not prove a panacea for Soviet energy problems caused by a future decline in oil production.

- Gas will prove difficult to substitute for oil in several sectors of the Soviet economy, particularly agriculture and transportation. Gas con-

sumption will continue to grow in industry, where its use is already substantial. Electric power generation will also provide a significant area of gas-for-oil substitution in the early 1980s.

- Gas will not match oil as a hard currency earner by 1980, although it probably will become the leading Soviet trade commodity well before 1985, earning several billion dollars a year.

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USSR: Development of the Gas Industry

Introduction

Soviet natural gas production until recently has drawn much less attention than Soviet production of oil, which currently constitutes 45 percent of domestic fuel output versus 24 percent for gas and 28 percent for coal. Natural gas, however, is the most dynamic sector of Soviet fuel production. Oil production faces serious problems stemming primarily from (a) declining output in the once-prolific Urals-Volga region in the European USSR and (b) peaking production at the largest oilfields in West Siberia. No other large Soviet oil deposits have been discovered in several years, and recent CIA studies have projected a decline in oil production sometime in the next few years. The Soviet gas industry, on the other hand, has grown rapidly—despite its repeated failure to meet plan goals—to become second only to that of the United States. Its impressive capacity for continued expansion suggests that its importance to both foreign and domestic consumers will eventually approach that of oil.

This paper is intended to provide a comprehensive reference work to facilitate evaluation of the gas industry's current performance and its prospects for growth during the next few years. *Section I* provides an overview of the gas industry's postwar development, discussing investment trends in the industry and utilization of gas by other economic sectors. *Section II* discusses the current status of Soviet gas reserves and the prospects for future additions. The rising importance of West Siberia to future increases in gas output is the focus of *Section III.* The progress and problems of the Soviets' massive gas pipeline system are discussed in *Section IV. Section V* covers the growth of Soviet gas exports to Eastern and Western Europe and imports from the Middle East. *Section VI* surveys the Soviet gas industry's current and future needs for Western equipment. *Section VII* evaluates the gas industry's prospects through the 1980s, focusing on obstacles to rapid growth in production, rising industry costs, and the likely role of gas in Soviet domestic energy consumption and foreign energy trade.

This paper is the third in a series of studies on the Soviet energy industry. It follows *Prospects for Soviet Oil Production,* ER 77-10270 (April 1977), and *Prospects for Soviet Oil Production: A Supplemental Analysis,* ER 77-10425 (July 1977).

The term "gas industry" will refer to the activities of the several ministries involved in the different phases of gas exploration, extraction, and transport. Although the Ministry of the Gas Industry is the principal government agency involved in Soviet gas production, the Ministry of the Petroleum Industry is responsible for a large portion of annual gas extraction—18 percent in 1977. The Ministry of Geology and the Ministry of Construction of Petroleum and Gas Industry Enterprises also have considerable responsibility for gas industry operations.

I. Postwar Development

The Soviet gas industry was largely neglected until the mid-1950s. Before World War II, gas played only a small role in energy supplies—mainly as a local fuel in the oil producing regions. After the war, the USSR concentrated on restoring coal and oil production and infrastructure in European Russia. Spurred by the discovery of large gas deposits in the early 1950s, however, gas output grew very rapidly after 1955, growing as a share in total supplies from 2 percent in 1955 to 24 percent in 1977 (see figure 1 and table J-5). Soviet planners reasonably expect the industry to achieve an increasing share by maintaining a substantial growth rate

during the balance of the Tenth Five-Year Plan (1976-80) and beyond. [1]

A. Early Development

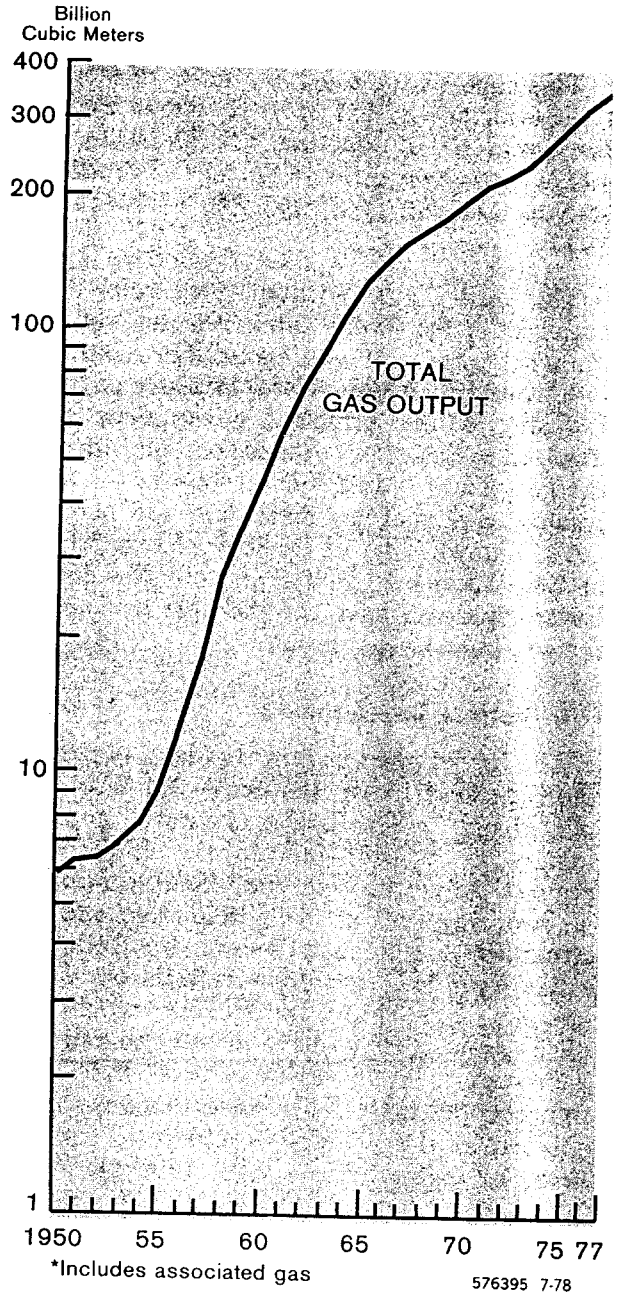
As in the case of other major world producers, the USSR was slow to expand its gas industry. The Soviets were unaware of their vast natural gas resources until after World War II.[1] Initially, production was limited primarily to associated gas recovered in conjunction with oil production in the Trans-Caucasus oilfields. Only toward the late thirties did the industry open its first Ukrainian natural gasfields and construct its first long-distance trunklines. Output remained small—hampered by German occupation during the war (see table J-1 [2])—and not until the midfifties did nonassociated natural gas constitute the bulk of Soviet gas production. The Soviets were reluctant to risk much capital exploring for a fuel which included uncertain reserves and which at that time was more dangerous and expensive to exploit than oil. Gas discoveries were usually the unexpected result of oil exploration; they generally proved small and, therefore, were often not developed. However, when, together with improved extraction and transport technologies, major Ukrainian natural gas discoveries were made in the early fifties, such obstacles were reduced.

B. Take-Off in Growth

Following the large Ukrainian gasfield discoveries, the jump in gas output and reserves proved dramatic (see figure 2 and tables J-2 and J-9). Average annual growth in production during 1956-77 was 18 percent, compared with 12 percent—computed from a smaller base—in the previous 25 years. Growth in gas extraction proceeded at a rate higher than that for crude oil production in all five-year periods after 1955 (see table 1). By the early seventies, USSR output was surpassed only by the United States.[2] As a

USSR:
Natural Gas Production*

Figure 2

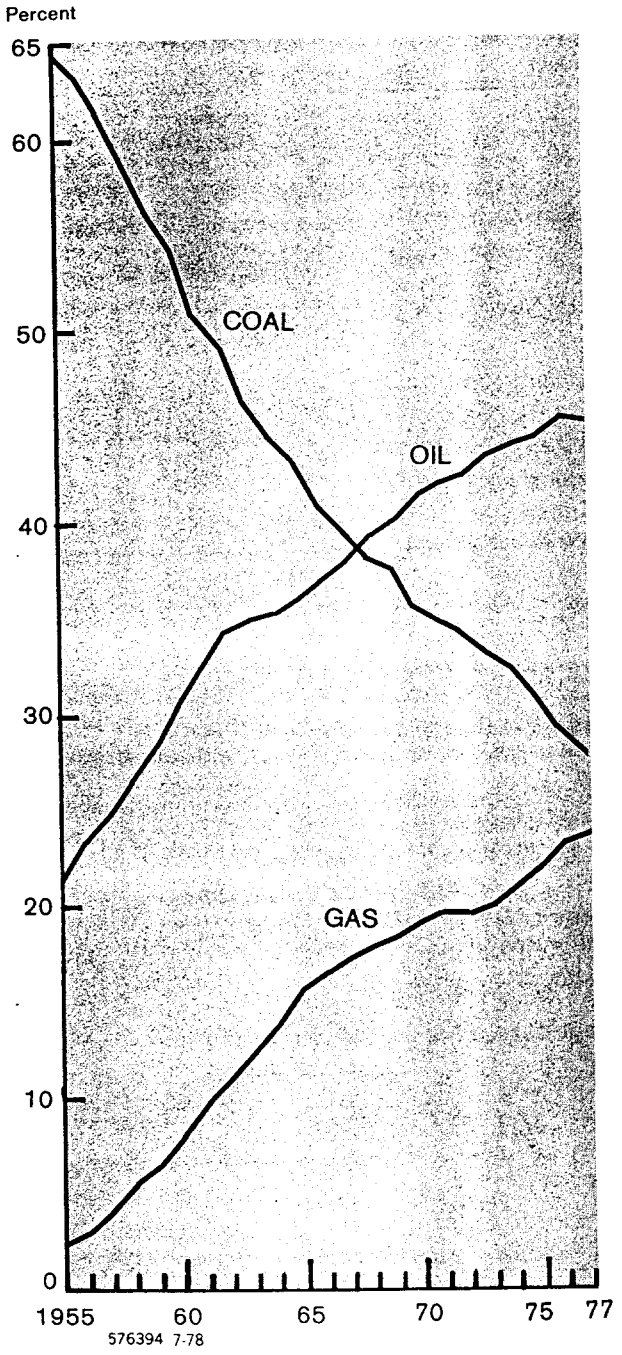


[1] Because CIA anticipates an absolute decline in oil output, its projections for production of oil and alternative fuels for 1978-85 show gas exceeding oil by a wide margin by 1985. For a detailed discussion of Soviet oil production problems, see CIA publication *Prospects for Soviet Oil Production,* ER 77-10270 (April 1977), and *Prospects for Soviet Oil Production: A Supplemental Analysis,* ER 77-10425 (July 1977).

[2] Appendix J consists of 27 statistical tables.

Figure 1

USSR:
Share of Major Fuels
in Total Fuel Production



result of increased exploration, gas reserves (proved and probable) increased more than 40 times during the 1956-76 period, averaging an estimated yearly growth of 19 percent to reach

Table 1

Gas and Oil Production

Percent [1]

	Gas	Oil
1951-75	16.9	10.8
1951-55	9.2	13.3
1956-60	38.2	15.9
1961-65	23.0	10.4
1966-70	9.2	7.7
1971-75	7.9	6.8
1976-80 Plan	8.5	5.5
1976	10.8	5.9
1977	7.8	5.1

[1] Average annual rates of growth

28 trillion cu m. Pipeline transport capacity has similarly expanded at a steady—although below-plan—pace.

Growth in both reserves and production has relied principally on a few fields.[3] Discovery and fairly rapid development of the North Stavropol' (North Caucasus) and Shebelinka (Ukraine) fields in the midfifties sparked and maintained early output increases; addition of a number of other large fields—especially Uzbek's Gazli—supported further expansion into the midsixties (see table 2). Thirteen fields during 1956-65 accounted for 56 percent of national production and approximately 40 percent of reserves. Shebelinka and North Stavropol' alone provided 30 percent of total output. Athough the Soviets currently are producing gas from more than 300 fields[4]—with more than 5,000 exploitation wells[5]— they are still relying on a few major fields, particularly in West Siberia, to provide most growth in output in the eighties.[6]

C. Investment

Investment in the gas industry grew slowly from 1946 through the early sixties but increased rapidly thereafter (see table 3), outpacing investment in other energy sectors during 1966-76 (see table 4). As a result, while the oil sector still consumes the largest portion of total annual investment in Soviet energy industries (roughly 35 percent in 1976), the share of gas has risen from 10 percent in 1965 to 17 percent in 1976. The value of the stock of plant and equipment in

Table 2

Major Gas Fields [1] Producing in 1965

Gas Field	First Year of Production	Billion Cubic Meters: Initial Reserves (A + B + C_1) [2]	Billion Cubic Meters: Cumulative Production
Shebelinskoye	1956	402.3	104.1
North Stavropol'skoye	1956	223.4	70.9
Gazli	1961	480.0	25.7
Ugerskoye	1946	36.8	25.0
Karadag	1956	34.1	23.9
Stepnovskoye	1958	27.6	17.6
Leningradskoye	1958	57.6	14.9
Bilche-Volitskoye	1949	41.0	14.8
Rudkovskoye	1957	32.1	13.5
Korobkovskoye	1961	89.7	11.6
Maikopskoye	1960	94.9	10.7
Berezanskoye	1963	61.0	9.6
Staro-Minskoye	1961	33.6	8.6

[1] Source: Iain F. Elliot, *The Soviet Energy Balance*, New York (1974), p. 18.

[2] Including:

Category A: reserves of those deposits on which detailed information is available from a network of wells completely covering each area.

Category B: reserves of those deposits on which information is available from a minimum of three wells yielding "commercial" flows of gas.

Category C_1: (a) reserves of newly discovered deposits on which information is available from two or more wells yielding commercial flows of gas and (b) reserves presumed to exist in parts of structures directly adjacent to those with higher category (A + B) reserves.

The A + B + C_1 figures refer only to natural gas reserves and do not include reserves of associated gas (gas extracted along with oil). It is uncertain whether published data for A + B + C_1 reserves include only those that are economically exploitable with current technology ("balansoviye" reserves), but available evidence suggests that generally they do.

Soviet and Western reserve concepts differ. Soviet A reserves plus some portion of adjacent B reserves correspond to the US "proved reserves" category. The remainder of B reserves and some fraction of the C_1 reserves fall into the US "probable" classification. Most of the remainder of the C_1 reserves fall into the US "possible" category.

Table 3

Capital Investment in the Ministry of the Gas Industry [1]

	Billion 1955 Rubles
1946-50	0.1
1951-55	0.4
1956-60	1.5
1961-65	3.2
1966-70	4.0
1971-75	10.9
1976-80 [2]	19.0

[1] Including investment for pipeline construction. Sources: *Review of Sino-Soviet Oil* (March 1969), p. 10; *Gazovaya promyshlennost'* no. 11, (1976), p. 12.

[2] Plan.

Table 4

Capital Investment [1] in Energy Industries

Industry	Index: 1965=100 1965	1970	1975	1976
Electricity [2]	100	123	149	153
Coal	100	128	124	129
Oil [3]	100	122	186	202
Gas [3]	100	170	293	306

[1] Investment flows of reproducible fixed assets expressed in constant 1973 prices. Source: *Narodnoye khozyaystvo* (1975), p. 508; (1976), p. 438.

[2] Including investment in all forms of electric power generation.

[3] Does not include investment in pipeline transport. Inclusion of such investment would have boosted the index shown above.

Table 5

Growth of Fixed Capital [1] in the Fuel Sector

Percent[2]

	1961-65	1966-70	1971-75
Total fuels[3]	7.3	7.3	7.4
Gas industry[4]	25.0	15.1	21.0

[1] In constant 1973 prices gross of depreciation. Source: *Narodnoye khozyaystvo,* various issues.

[2] Average annual rates of growth.

[3] Excluding electric power and oil and gas pipelines.

[4] Ministry of the Gas Industry. Excluding gas pipelines.

Table 6

Natural Gas Consumption[1]

Percent[2]

1961-75	13.0
1961-65	23.1
1966-70	9.3
1971-75	7.3
1976	8.6
1977	6.4

[1] Apparent consumption. Sources: *Narodnoye khozyaystvo* SSSR and *Vneshnyaya torgovlya* SSSR, various issues. CIA estimates for 1976-77.

[2] Average annual rates of growth.

the Ministry of the Gas Industry (which accounts for most of the fixed capital stock of the gas industry) similarly has climbed steadily (see tables 5 and J-4). By 1976, the Ministry's stock of reproducible fixed assets had reached 14 billion rubles[7]—only 30 percent less than that for the oil industry.[8] As expected, because of very long transmission distances to consumers, pipeline construction has taken the bulk of investment allocations (see tables J-3 and J-4).

D. Trends in Use

Reflecting the rising share of gas diverted to exports, national consumption of gas has climbed more slowly than production (see table J-6). Although the earlier exceptionally high growth rates of domestic gas use have declined (see table 6), the absolute volume has increased by 1,000 percent over that of the late fifties.

Meanwhile, the trends of regional and sector consumption have been generally upward (see tables J-7 and J-8). Industry has received more than one-half of the annual output of gas, with consumption concentrated in the traditional industrial centers of the European USSR. The more remote eastern areas are now using a larger share of the gas they produce, which reduces the proportion of their output available for transmission elsewhere. The growth in use of gas as industrial boiler and furnace fuels in West Siberia, Central Asia, and the Urals reflects this trend (see table J-9).

The major sectoral development has involved a decline in the shares of gas consumed by electric power plants [3] and the oil and gas industry, [4] and a substantial rise in the share of gas absorbed by the metallurgical and chemical industries. [9] That shift reflects both a Soviet effort to increase the use of gas as a raw material rather than as a fuel and the development of new production technologies. Although lagging greatly behind the developed West in adapting the use of gas for heavy industrial purposes, the USSR in the past decade has considerably increased the use of gas in such areas as the petrochemicals industry (for example, in ammonia production) and in gas converters for steel production. [5] Gas use by electric power plants may also have grown more slowly because of reduced need for buffer supplies of gas for handling peak demand periods in winter.

The share of gas supplies devoted to household consumption has increased only slightly. [6] With installation of extensive urban distribution systems both technically difficult and expensive, the Soviets have given priority to large-diameter transmission pipelines leading to large industrial

[3] The actual amount of gas consumed by electric power generation has, nonetheless, grown substantially.

[4] Recent evidence does indicate, however, that gas use by the gas industry itself, notably for operating gas turbine compressor units on major gas pipelines, is climbing and perhaps reached 30 billion cu m by 1977—9 percent of total production. *(Gazovaya promyshlennost',* no. 4 (1977), p. 6).

[5] Although use of gas in electric power generation grew by 600 percent during 1958-75, its share of national consumption has fallen by 11 percent. Reflecting the very rapid expansion of gas as a raw material, use in the chemical industry—notably for ammonia production—has increased 75 times, and use of gas in metallurgy has risen 23 times.

[6] Precise determination of household consumption is difficult, because of extensive use by urban apartments of byproduct heat from gas-burning heat-electricity plants.

consumers and electric power plants that produce both space heat and electricity.

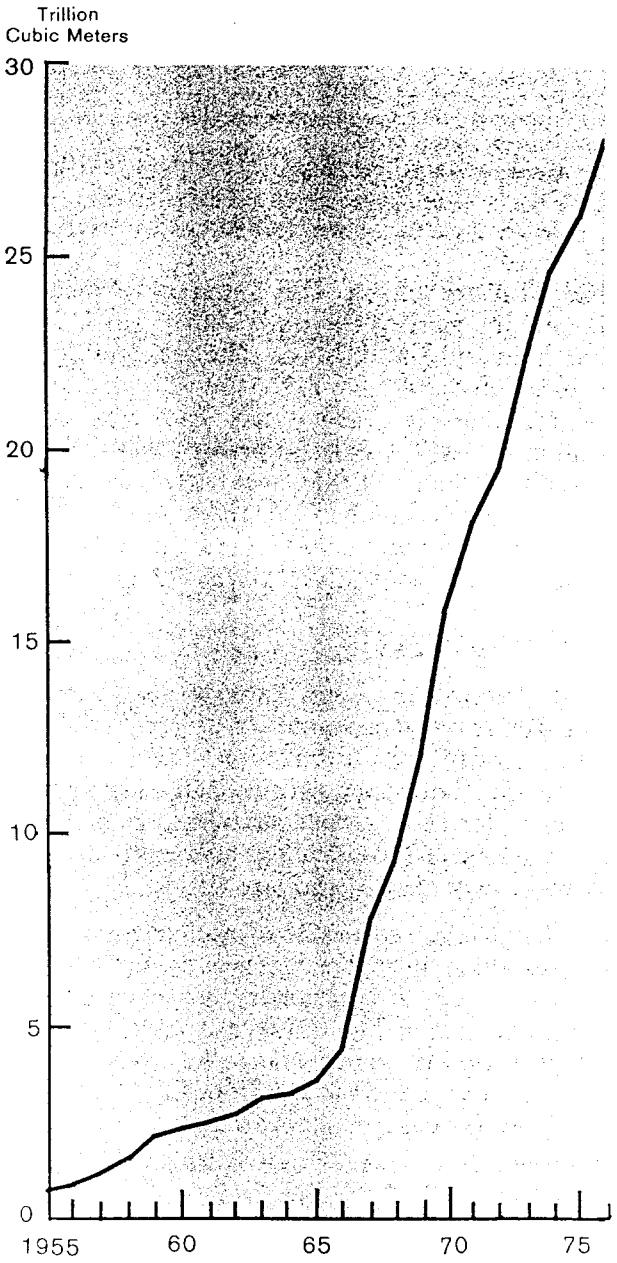
II. Reserves

Soviet gas production's postwar growth has been based on (a) the large size of the country's gas reserves and their fairly rapid development and (b) the shift in exploitation from the dwindling reserves of the European USSR to the more recently discovered reserves of Central Asia and West Siberia.

A. Growth of Reserves

Discovered gas reserves have increased dramatically since the midsixties. In 1961, only 239 gas or gas condensate deposits were known to exist; by 1975 there were 650. [10] Growing at an average annual rate of 20 percent, reserves in Soviet categories A + B + C_1 [7] climbed from 3.6 trillion cu m in 1965 to 28 trillion cu m in 1976 [11] (see figure 3 and table J-10), giving the Soviets, by their own account, the world's largest gas reserves. [8] Additions to proved and probable reserves rose most sharply—by 35 percent per year—during the last half of the sixties, when many of the largest fields in Central Asia and West Siberia were discovered. During 1971-76 the average annual growth slowed to 10 percent. Nevertheless, the ratio of reserves to production for natural gas has improved dramatically. After declining throughout the early sixties, the ratio rose from a low of 28 in 1965 to a peak of 95 in 1973 (see table J-10).

USSR: Gas Reserves* Figure 3



* Corresponds very roughly to the Western reserve categories of proved, probable, and possible.

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[7] For a description of coverage by reserve category see footnote 2 for table 2.

[8] It is possible that the Soviets have recently revised downward their gas reserve estimate. Although Soviet data released in 1976 and 1977 indicated that reserves of 28 trillion cu m had been reached, recent Soviet statements have failed to give a current reserves estimate and suggest that the figure may be lower, perhaps around 23 trillion cu m. See *Journal of Commerce*, 5 June 1978, p. 4. This paper will use the estimate of 28 trillion cubic meters. As noted above—footnote to table 2—differences between Soviet and Western concepts of reserves, moreover, complicate global comparisons; Persian Gulf reserves estimated under Soviet criteria would probably prove much larger than the USSR's. In addition, Soviet reserve estimates should be used with some caution, since unrealistically high figures have been noted in the past.

B. Geographic Shift

West Siberia has clearly emerged since the late sixties as the leading source of future Soviet gas production. [12] Paralleling developments in crude oil, the share of total reserves of the old European USSR gasfields—principally in the North Caucasus (Stavropol' and Krasnodar' Krays) and the Ukraine—has diminished rapidly as a result of intensified extraction and the lack of major new discoveries (see tables 7 and 8). Meanwhile additions to reserves in West Siberia's Tyumen' Oblast and—to a lesser extent—in Central Asia's Turkmen SSR and in the Southern Urals' Orenburg Oblast have been substantial (see table J-11). [9] The older fields held about 65 percent of proved plus probable reserves in 1956 but constituted a little less than 6 percent

[9] See appendixes A, B, and C for further details on the European USSR, Central Asian, and West Siberian fields.

Table 7

Natural Gas Reserves (A + B + C_1) of Selected Regions as a Share of Total Soviet Reserves [1]

Percent

	Older Producing Regions				Newer Producing Regions			
	Ukraine SSR	Krasnodar' Kray	Stavropol' Kray	Three-Region Total	Turkmen SSR	Tyumen' Oblast	Orenburg Oblast	Three-Region Total
1951	40.6	0	15.4	56.1	0	0	2.4	2.4
1956	21.5	10.9	32.6	64.9	5.1	0.5	0.7	6.4
1960	24.7	16.3	11.3	52.3	0.6	2.3	0.8	3.6
1966	18.4	13.0	6.6	38.0	10.6	11.2	0.7	22.5
1971	5.1	0.6	1.3	7.0	9.7	58.7	7.1	75.6
1974	3.9	1.1	0.8	5.7	9.6	61.3	9.4	80.4

[1] Percents are calculated from beginning of year data on reserves. Because of rounding, components may not add to the totals shown.
Source: A.D. Brentz, et. al., *Ekonomika gazodobyvayushchey promyshlennosti*, Moscow (1975), p. 25.

Table 8

Additions to Natural Gas Reserves (A + B + C_1) [1] in 1976

Region	Billion Cubic Meters		Percent of Plan Fulfilled
	Planned	Actual	
USSR	2,221	2,230.7	100.4
European section	347	192.7	55.5
Asian section	1,874	2,038.0	108.8
RSFSR			
Northwest region	84	22.0	26.2
Volga region	10	6.2	62.0
Urals region	163	83.0	50.9
North Caucasus	22	12.5	56.8
West Siberia	1,410	1,616.5	114.6
East Siberia	35	0	0
Far East	153	149.0	97.4
Ukraine SSR	68	69.0	101.5
Transcaucasus	13	13.0	100.0
Central Asia	263	259.5	98.7

[1] Source: *Geologiya, bureniye i razrabotka gasovykh mestorozhdeniyy*, no. 4 (1977), p. 3.

by 1974. Reserves of the newer regions conversely have grown from 2.4 percent of the national total in 1951 to more than 80 percent in the mid-1970s. The diverging trends in growth of reserves in old and new producing regions are reflected in widely different ratios for reserves to production (see table 9).

As in the midsixties, when six fields in the European USSR [10] accounted for 48 percent of national output, [13] growth in gas production through the early eighties will rely primarily on a handful of deposits. Northern Tyumen' Oblast has provided most of the growth in the USSR's reserves in the past decade (see appendix C). [14] During 1966-77 it contributed 70 percent of additions to the A + B + C_1 categories and by 1977 held more than 60 percent of Soviet reserves. Eight northern Tyumen' fields—Urengoy, Yamburg, Zapolyarny, Medvezh'ye, Kharsavey, Bovanenko, Semakov, and Neitinsk—together hold more than 80 percent of the region's reserves. Combined with the Shatlyk (Turkmen SSR) and Orenburg fields, they account for approximately 60 percent of Soviet reserves. Of these only Shatlyk, Medvezh'ye, and Orenburg are substantially developed. The remainder are undergoing initial preparation or are still being explored. Most reserve additions through the early eighties probably will come from further discoveries on Tyumen' Oblast's Yamal Peninsula, where exploration currently is under way.

[10] Shebelinka, North Stavropol', Gazli, Karadag, Ugersk, and Berezan.

Table 9

Natural Gas Reserves/Production Ratios for Selected Regions [1]

	1960	1965	1973
Older regions	41.9	17.4	14.0
Ukraine SSR	38.2	16.3	12.4
Krasnodar' Kray	70.3	19.9	21.8
Stavropol' Kray	30.6	16.4	12.7
Newer regions	113.0	358.0	320.4
Turkmen SSR	57.0	245.4	68.5
Orenburg Oblast	35.2	47.5	236.8
Tyumen' Oblast	[2]	[2]	746.2

[1] Source: Brentz, *Ekonomika gazodobyvayushchey promyshlennosti*, pp. 25, 39.

[2] Although reserves were large, production was negligible.

C. Reserve Characteristics

Soviet natural gas is of generally good quality, with a high methane content. [15] Handling gas in some areas in the future, however, will not prove to be easy. Much of the gas in Central Asia, Orenburg, and the European USSR contains significant amounts of hydrogen sulfide and carbon dioxide, which must be removed. [16] Condensate is a problem [11] both in these regions and in West Siberia and in the Komi ASSR, where hydrate [12] formation will complicate extraction. Moreover, as exploitation enters lower depths of such multistrata fields as Urengoy, large condensate reserves could pose a greater extraction problem than at the outset of production. Formation pressure also will create difficulties in some regions. Much of the gas in Turkmen is under extremely high heat and pressure, requiring special wellhead and collection equipment able to withstand such conditions. On the other hand, some Tyumen' fields—possessing low pressure even before production—could experience serious pressure drops a few years after extraction begins, [17] which would leave much valuable condensate in the ground. Soviet gas production through the 1980s will, accordingly, require substantial improvement of gas extraction and processing capabilities (see appendix D). Increased compressor power to maintain adequate pressure in major Siberian pipelines, because of falling gas pressure at the fields themselves, will be required. Protection of trunklines from corrosion and the expansion of use of gas as feedstock in petrochemical industries will

[11] Condensate consists of gas liquids in the deposit that have been separated from the dry gas by high heat and kept in liquid form by high pressure. When extracted, condensate begins to vaporize under the lower surface pressure. Cooler temperatures at the surface, however, return part of the vaporized condensate to liquid form. Processing plants at the field complete the recompression, after which the condensate is separated into butane, propane, ethane, and methane. Condensate must be removed from the gas before the latter is transmitted through the pipeline. If it is not, the condensate can vaporize in the line, damaging the pipe and causing other transmission problems. At many fields in Siberia where processing facilities do not yet exist to refine the condensate into usable products, the condensate is wastefully discarded.

[12] Hydrates result from the cooling of warm gas as it flows to the surface. The condensation causes water vapors to collect at the top of the well and down hole near perforations in the well casing. The hydrates tend to plug the flow apertures in both areas, and at low surface temperatures may freeze, causing valves to stick or split.

require effective removal of gas impurities and byproducts.

D. Emerging Problems in Expanding Reserves

The Soviets face growing difficulties in adding to their gas reserves. Major increments will prove harder and more costly to obtain. Substantial new discoveries are likely, but overall growth in reserves will slow considerably, despite the planned step-up in capital in exploration outlays. The increasing depth and complexity of promising formations and their location in inhospitable, distant regions will pose new obstacles to Soviet exploration capabilities, including rapidly rising exploration costs.

Prospecting [13] represents a growing, though small, percentage of Soviet gas industry investment. It jumped 600 percent during 1971-75 alone. Exploration may account for almost two-thirds of total drilling for gas, as shown in the tabulation below.[18]

	Percent
1961-65	43
1966-70	57
1971-75	63

[13] Published ruble expenditure figures for this sector of the industry apply to both prospecting (for example, seismic mapping) and actual exploratory drilling.

The average depth for exploratory drilling increased only 33 percent during 1962-75, but the Soviets expect it to grow by another 30 percent in 1976-80, and recent drilling results suggest that it may increase even more than that.[19] Reserves currently being exploited in West Siberia mainly are at depths of 1,000-2,000 meters, thereby contributing to a relatively low national average (see tables 10 and 11). However, in some important producing areas—notably Turkmen, Komi ASSR, and the Ukraine—most proved and probable reserves are located at depths greater than 2,000 meters. Further West Siberian exploration will similarly have to search to greater depths.

Technology will pose considerable problems. Soviet drilling practices, predominantly based on the turbodrill, become much less efficient at

Table 10

Average Gas Well Depth [1]

	Meters
1961	1,580
1965	1,775
1970	1,857
1975	2,100
1980	2,700

[1] Source: V. A. Smirnov, "Gazovaya promyshlennost'," *Ekonomika organizatsiya promyshlennogo proizvodstva*, no. 5 (1975), p. 58.

Table 11

Distribution of Gas Reserves,[1] January 1971

Region	Depth			
	Less Than 1,000 Meters	1,000-1,999 Meters	2,000-3,000 Meters	More Than 3,000 Meters
	Percent			
USSR	9.7	67.4	14.4	8.5
RSFSR	9.2	79.8	9.9	1.1
Komi ASSR	2.8	1.7	90.9	4.6
Orenburg Oblast	1.5	98.5	0	0
Tyumen' Oblast	9.6	89.9	0.5	0
Ukraine SSR	5.1	13.8	53.8	27.2
Kazakh SSR	20.0	42.5	37.5	0
Uzbek SSR	33.0	34.1	32.1	.8
Turkmen SSR	4.1	19.7	17.3	58.9
Tadzhik SSR	0	31.8	57.4	10.8
Kirgiz SSR	11.5	60.9	27.6	0

[1] $A + B + C_1$. Source: V. N. Kalchenko, *Ekonomika gazovoy promyshlennosti*, Kiev (1974), p. 72.

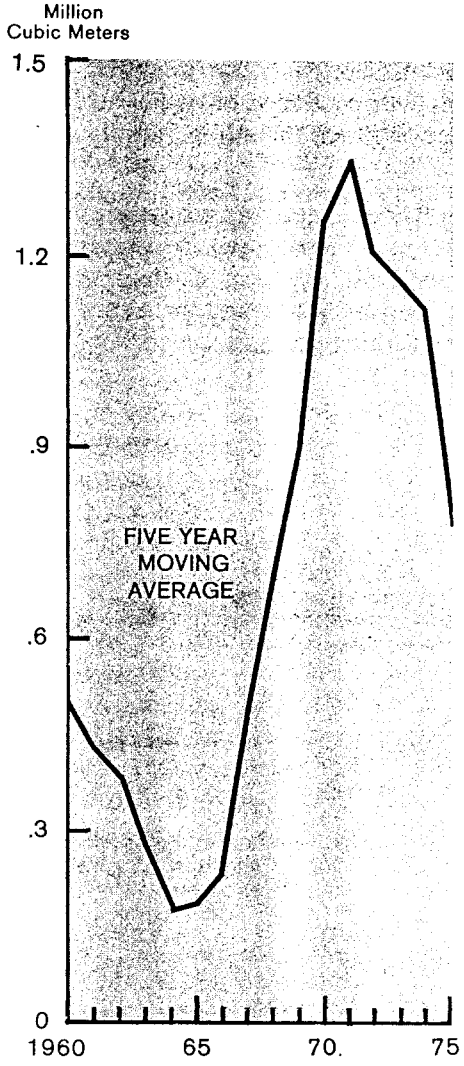
depths of more than 2,000 meters. [14] This fact, compounded by limited use of quality seismic surveying equipment, has restricted the success of exploratory drilling. [15] As a result of inadequate seismic surveying, only minimal expansion of reserves has been achieved in older producing regions, where potential gas-bearing formations are very deep.[20] The technological difficulty of locating new reserves has prompted exploration crews to spend the bulk of their time on step-out drilling [16] in known producing zones rather than risking failure in promising but unexplored areas.[21] After rising sharply in the late 1960s, reserve additions per meter drilled dropped steadily in the early 1970s (see figure 4 and tables 12 and J-12). Because of the continuance of these difficulties and because most major gas deposits in Central Asia and northern Tyumen' Oblast may have been discovered, annual discoveries probably will level off or decline during 1976-80, although they will remain far higher than before 1965.

E. New Regions

Significant expansion of gas reserves beyond the mid-1980s will rely in great part on exploration in East Siberia, in the Soviet Far East, and offshore. Moscow may be planning a major exploration drive in East Siberia and Yakutsk ASSR during the remainder of the decade.[22] Although the Soviets estimate large reserves in the eastern regions—13 trillion cu m in Yakutia alone—exploration in West Siberia, the Urals-Volga, and other regions has received higher priority during the past 15 years. Only 0.5 meters have been drilled per square kilometer in East Siberia compared with 20 meters in the

Figure 4

USSR:
Addition to Natural Gas Reserves*
Per Meter of Exploratory Drilling



* Corresponds very roughly to the Western reserve categories of proved, probable, and possible.

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[14] The turbodrill, which constitutes almost 80 percent of all Soviet drilling rigs for oil and gas, employs drilling fluid under high pressure to drive the drill bit. The rotary drill, which is the predominant drilling rig type used in the West, employs a drill bit attached to high-quality drill pipe. The mechanized turning of the pipe by the drilling rig—plus the weight of the pipe—drives the bit. Turbodrill down-hole components generally wear out faster than those for rotary drills.

[15] Most Soviet seismic recording is still done on analog tape employing technology used in the United States in the 1950s. This leads to poor recording of important geological data.

[16] Step-out drilling is the sinking of wells to further define the size and increase the ratio of reserves to production of a known oil or gas deposit.

Table 12

Exploration for Natural Gas in Selected Gas Production Associations,[1] 1971-75

Production Association	Exploratory Drilling (Thousand Meters)	Reserves Added A + B + C_1 (Billion Cubic Meters)	Reserves Added per Meter Drilled (Thousand Cubic Meters)
Tyumengazprom	120.0	8,655.1	72,126
Turkmengazprom	298.9	704.8	2,358
Uzbekgazprom	45.2	5.4	119
Kubangazprom (Krasnodar' Kray)	499.6	16.5	33
Stavropolgazprom	107.0	3.0	28

[1] Sources: *Geologiya nefti i gaza*, no. 6 (1976), pp. 16-18; A. D. Belorusov, et al., *Problemy razvitiya i razmeshcheniya proizvodstvennikh sil zapadnoy sibirii*, Moscow (1976), p. 19; *Geologiya bureniye*, no. 4 (1977), p. 3

Urals-Volga region. Drilling coverage for Yakutsk is similarly light. Proved and probable reserves in East Siberia and Yakutsk are low as a result, but Moscow may eventually expand the area covered and intensify drilling efforts in promising locations.

Even if East Siberia and the Far East have extensive reserves, many of their potential gas-bearing structures are much deeper than gas-bearing structures in West Siberia. More than 60 percent of Yakutia's discovered reserves are located at or below 3,000 meters.[23] Moreover, many formations will prove complex for surveying. These problems will be aggravated by the great distances from supply bases and current transport lines and by difficulties with permafrost possibly exceeding those in northern Tyumen'. Completion by the early 1980s of the Baikal-Amur Railway parallel to but north of the Trans-Siberian line will help, but huge capital investments in additional infrastructure will still be needed.[17]

Exploration, therefore, will probably move slowly during 1976-80, and reserve additions will increase only gradually, particularly if harsh climatic conditions bring continued drilling problems in both East Siberia and Yakutsk and if seismic surveying is not widely adopted. The risk-avoiding emphasis on step-out rather than exploration drilling will also hamper effectiveness.

Offshore formations may hold several trillion cubic meters of gas, but they have received even less attention than the East Siberian and Far Eastern economic regions.[18] Structures in the Kara and Barents Seas—adjacent to northern Tyumen'—are estimated to have the largest undersea Soviet reserves, but no major prospecting has been done. Offshore Sakhalin reserves, once estimated to be quite large, have been appraised downward as a joint US-Japanese-Soviet exploration effort continues. Proved reserves in the Caspian Sea and off the Crimea are not large but represent the best explored of Soviet offshore formations, and drilling there could be substantially increased.

Soviet offshore capabilities lag substantially behind the West. With many undersea structures located well below 3,000 meters (and under at least 100 meters of water), poor technology has clearly held up progress. The Soviets do not have the sophisticated offshore rigs, drilling and subsea well completion equipment, and offshore pipeline technology required for large-scale exploration and exploitation of offshore gas deposits, particularly those under arctic waters. Until

[17] In Irkutsk, the focusing of most exploratory drilling near the Trans-Siberian railway in the past—while logistically practical—in fact reduced aggregate results since the most promising exploration sites known at that time were further north, away from all-weather transport routes. *Review of Sino-Soviet Oil* (June 1975), p. 15.

[18] For a general discussion of Soviet offshore gas potential, see *Offshore Magazine* (April 1976), pp. 63-67.

Western-type equipment is purchased and used more widely by the Soviets, most USSR offshore zones probably will remain relatively unexplored and untapped.

III. Production

Soviet gas production in 1977 was 346 billion cu m, exceeding 1975 by 57 billion cu m. Production thus achieved a 9.4-percent average annual growth during 1976-77, well above the 8.5-percent average needed to reach 435 billion cu m by 1980—the upper limit of the 1976-80 five-year plan. Gas output currently is planned to increase to 370 billion cu m in 1978 and to 401 billion cu m in 1979.[24]

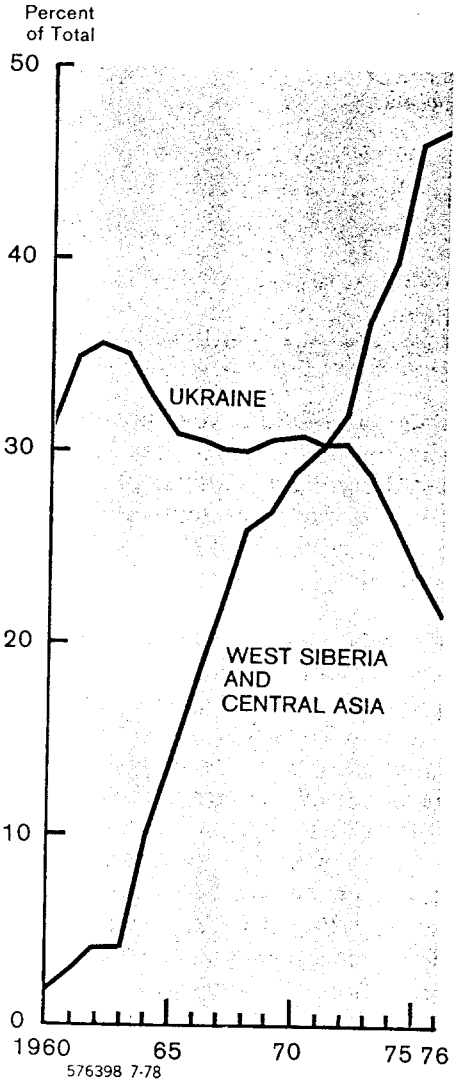
A. Growth in the East; Decline in the West

1. Recent Trends. The discoveries in West Siberia and Central Asia of the USSR's largest gas reserves have been reflected in the steady rise in production in these newer regions and in the equally steady decline of production from the USSR's older fields.[25] The output of Stavropol' and Krasnodar' Krays and the Ukraine constituted 61 percent of Soviet gas production in 1965, but fell to 30 percent by 1975 (see tables J-13, J-14, and J-15). North Caucasus production dropped 43 percent during 1971-75. Ukrainian output increased only 13 percent in the same period and began to decline in 1977.

By 1972 combined Central Asian and West Siberian production had surpassed that of the Ukraine (see figure 5). The former two regions provided only 14 percent (18 billion cu m) of Soviet gas supplies in 1965, but their combined output grew at an average annual rate of 21 percent during 1966-76, a sevenfold increase. Central Asia contributed most of the increase, growing from 17.9 billion cu m to 104 billion cu m—an average annual rate of 17.4 percent. West Siberian output increased from 0.6 billion cu m in 1966 to 68 billion in 1977—an average annual rate of more than 50 percent. Central Asia in 1977 provided almost one-third of Soviet gas production and West Siberia supplied 20 percent.

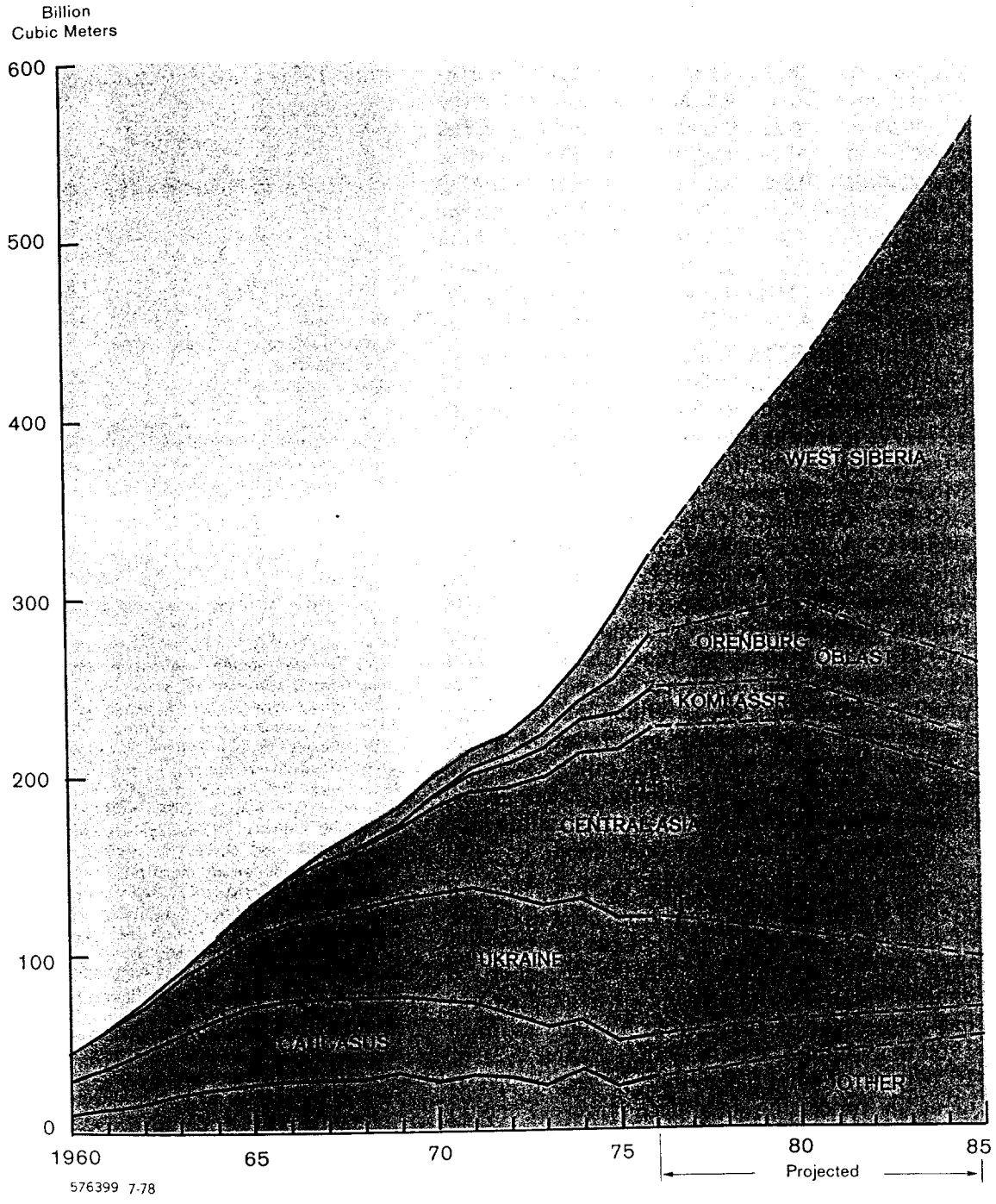
2. Future Growth. Most of the production growth in 1978-80—and virtually all output increases through 1990—will come from areas east of the Urals (see figure 6). Moscow expects the

USSR: Selected Regional Natural Gas Production — Figure 5



USSR:
Regional Production of Natural Gas

Figure 6



Ukraine's production to fall by approximately 12 percent during 1978-80, [26] but it will probably decline more rapidly. The drop in European USSR gas production during 1971-77 was offset primarily by Central Asian production. During the next decade, however, West Siberia's northern Tyumen' Oblast will have to make up for the Ukraine's sharp decline and provide most of the increase in total Soviet gas output. West Siberia is scheduled to become the leading producer by 1980, contributing one-third of Soviet output (see appendix C).[27] Central Asian production will grow more slowly, and its share of national production is targeted to fall to roughly 26 percent.

As previously, the industry's growth through the 1980s will in fact depend on the continued development of only a few large fields. During 1971-77, more than 95 percent of the additions to national production came from six fields: Medvezh'ye (Tyumen' Oblast); Vuktyl (Komi ASSR); Orenburg (Orenburg Oblast); and Shatlyk, Achak, and Naip (Turkmen SSR). During 1978-80 Turkmen [28] and Orenburg [29] will add some capacity, but the main growth will come from Vyngapur and Urengoy in Tyumen'. Urengoy, the USSR's largest known gas deposit, is expected by Moscow to produce 58 billion to 60 billion cu m within three years after coming on-stream in 1978. Beyond 1980, Urengoy and other Tyumen' fields—Zapolyarny, Yamburg, Yubilenoy, Kharsavey, and Bovanenko—will constitute the main sources of additional production.

Soviet gas output will also increase through greater use of associated gas from oil wells. Lack of equipment for handling such gas has forced a high rate of wasteful flaring for decades (see appendix D). The processing of associated gas has grown slowly, rising from 8 billion cu m in 1960 to 29 billion cu m in 1975 (see table J-2), or 10 percent of total gas output. Increased investment in processing facilities, however, should raise output substantially by 1980.

B. Increased Costs

Although costs of gas extraction are lower than those for oil or coal production, they are rising faster than production costs of any of the other Soviet energy industries. The drop in output from older fields and the difficulty of developing Siberian and Central Asian deposits have pushed costs up substantially. The cost in constant 1970 prices of extracting 1,000 cu m and

Table 13

Change in Production Costs in Constant Prices [1]

Percent [2]

Industry	1970 Over 1965	1975 Over 1970
Oil extraction	−3.0	12.6
Gas production [3]	8.5	45.9
Coal production	5.6	6.8
Electric power	0.1	2.4

[1] Expressed in "prices of the previous year." The official link relatives given in the annual statistical abstracts (for example, *Narodnoye khozyaystvo 1974*, p. 209) apparently are expressed in the form of a "link cost" index of the following form:

$$C_2 = \frac{\sum P_1 Q_2}{\sum P_1 Q_1}, \quad C_3 = \frac{\sum P_2 Q_3}{\sum P_2 Q_2} \quad \ldots$$

[2] The percent changes are based on absolute cost figures for the four industries. Those figures were derived by (a) extrapolating a benchmark cost figure for each industry by the official Soviet cost index for that industry to obtain a series of production costs (*sebestoimost'*) in constant prices and (b) adding to the derived *sebestoimost'* series (expressed in rubles/kopecks per unit of output) an interest charge on each industry's reproducible fixed assets.

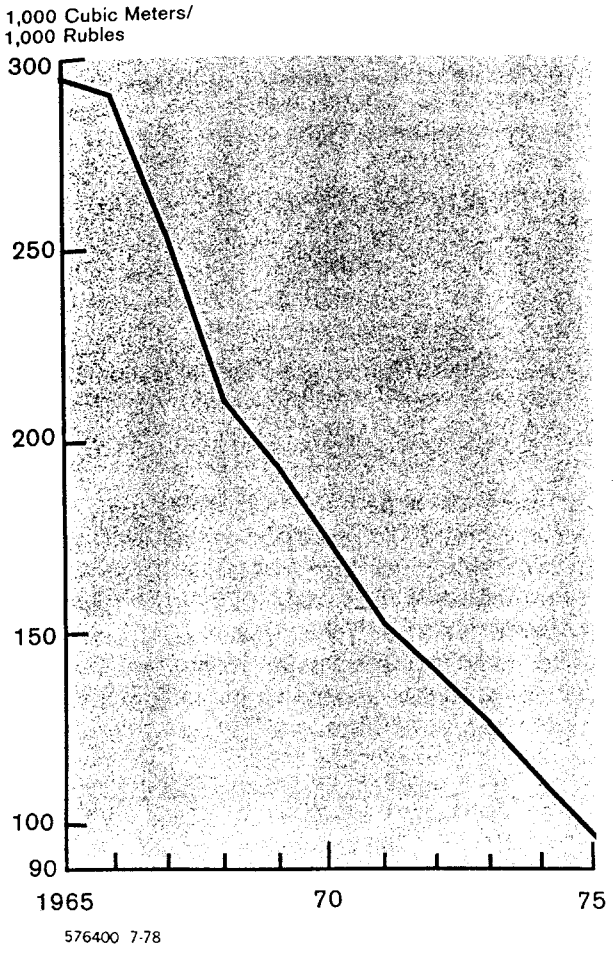
Benchmark cost figures for each industry were for 1970 or 1972. They were derived indirectly from official coefficients for amortization charges. For example, the 1970 cost (*sebestoimost'*) for oil was derived by (a) taking the 1970 amortization charge on fixed capital in the oil industry (*Narodnoye khozyaystvo 1970*, p. 1971); (b) dividing the total charge (in million rubles) by total 1970 oil production to derive an amortization charge per metric ton of oil produced; then (c) dividing that charge by its percentage of oil production's *sebestoimost'* for 1970 (p. 174), to produce an approximate *sebestoimost'* (in rubles) for 1 ton of oil. This benchmark figure was then extrapolated by use of the official cost index. Capital stock in constant prices for 1965 and 1970-75 was derivd by extrapolating 1972 capital stock figures for each industry (*Narkhoz 1974*, p. 62) through the official index for growth in capital stock (for example, *Narkohz 1974*, p. 196). The resulting series represents reproducible fixed assets in constant 1 July 1967 wholesale prices. The capital charge for the industries was added by taking the 12-percent interest of the derived stock figure for each year, dividing it by the total physical units produced that year, and adding the result to the base *sebestoimost'*.

Because the only charge for capital in official Soviet cost figures is an amortization (depreciation) allowance, a synthetic interest charge is incorporated. These cost figures embody—in the 12-percent interest charge—the "convention" used by Western scholars to derive an appropriate measure of capital's contribution.

[3] Does not include pipeline transport or storage.

Figure 7

USSR:
Output-Capital Ratio for Gas Extraction



processing it for transport declined steadily from 1955 to 1965, but then rose sharply from a low of 2.71 rubles in 1965 to 4.29 rubles in 1975.[30] Most of this increase occurred in the first half of the 1970s when unit costs rose by 46 percent. Costs for oil extraction, coal production, and electric power generation grew much more slowly (see table 13).

Total new fixed investment in gas extraction rose from 1.0 billion rubles in 1966-70 to 3.1 billion rubles in 1971-75.[31] At the same time, according to Soviet data, the ratio of output to capital stock dropped from 294 cu m per ruble in 1965 to 96 cu m per ruble in 1975 (see figure 7 and table J-16).[32]

Large investments in older gasfields will remain a drag on the industry's economic performance. The need to satisfy growing domestic consumption and export requirements will prompt continued efforts to slow the production decline from deposits in the European USSR. Losses in capacity at older fields have increased substantially. As a result, new investment in 1971-75 designed to compensate for output losses—by drilling new wells in aging fields or by developing new deposits both in older regions and in West Siberia and Central Asia—exceeded investment intended for major additions to national capacity.[33] During that period output/capital stock ratios for the older fields declined sharply (see tables J-16 and J-17).

A leading reason for the decline is higher drilling costs. Squeezed by rapidly increasing depths and steadily falling output, production wells in older producing areas have grown increasingly expensive to put into operation. The average depth of overall development drilling rose during 1971-75 from 1,745 to 2,100 meters. New gas deposits in many of the long-exploited areas—including most of Central Asia—are located even deeper. Wells sunk in those regions through 1980 will probably average between 3,000 and 4,000 meters, [34] depths that forced well costs in those regions to climb more rapidly than the national average of 14 percent during 1966-72 (see table 14). [35] Costs will continue to rise sharply if Soviet deep-drilling technology does not improve substantially, and they will be covered to a decreasing extent by growth in output per well. As more wells have been drilled in regions of declining capacity, production per well has nose-dived (see table J-18). [36] [19] Use of certain types of drilling rigs in prospective zones for which those rigs are not effective has also contributed to higher costs. [37]

[19] The average output per well for the USSR as a whole has not fallen steeply since peaking in 1965. A relatively high well average for West Siberia has partially offset a decline per well for the Ukraine and North Caucasus.

Table 14

Cost [1] of Development Wells

	1 January 1966			1 January 1973			
	Cost of Wells (Thousand Rubles)	Number of Wells	Cost per Well (Thousand Rubles)	Cost of Wells (Thousand Rubles)	Number of Wells	Cost per Well (Thousand Rubles)	Average Annual Increase (1966-72) in Cost per Well (Percent)
USSR	239,792	3,314	72.4	941,161	5,058	186.0	14.4
Ukraine	75,901	755	100.5	281,295	1,291	217.9	11.7
Uzbek	28,724	345	83.3	86,198	462	186.6	12.2
Krasnodar' Kray	37,740	468	80.6	122,760	735	167.0	11.0
Stavropol' Kray	15,000	389	38.6	68,520	787	87.0	12.3
Tyumen' Oblast	NA	NA	NA	NA	NA	450.0 [2]	NA

[1] "Balance sheet" costs (*"balansovaya stoimost'"*), expressed in current factor prices. Unlike costs in the data underlying table 13, interest charges on capital are not included. Sources: G. Z. Khaskin, et al., *Osnovnyye fondy gazovoy promyshlennosti*, Moscow (1975), p. 41; *Ekonomika gazovoy promyshlennosti*, no. 2 (1975), p. 12.

[2] Represents lower end of a range of 450,000 to 600,000 rubles given for Tyumen' gas well drilling (1,000 to 1,200 meters) in 1975.

The state of applied Soviet well drilling and completion technology has also contributed to greater well expense. Drill bits, drilling fluids, drill pipe, and casing are generally of poor quality by Western standards, and have caused up to 50 percent of total emergency downtime in recent years. [38] Improvement is essential for drilling deep wells in Central Asia, the Ukraine, and particularly in northern Tyumen'— where large high-capacity wells (144 to 166 mm in diameter and later possibly up to 273 mm) are being drilled in an arctic environment [39] in which the ground's freezing and thawing and the widespread presence of hydrates can place metals and other materials under tremendous stress. [40] Serious blowouts or well cave-ins could occur as a result. Wellhead equipment often cannot handle high-pressure, high-temperature gas, and serious production losses have resulted over the years at many major fields. Packer technology needed for extracting gas from two or more strata through one well is still primitive at most fields and as a result gas losses are large. [41] [20] Soviet interest in dual completion methods nonetheless is substantial, and it was attempted on more than 100 wells during 1971-75, [42] primarily at two of Turkmen's larger fields—Achak and Naip. [43] Gas losses at the latter two fields, resulting from faulty packers and wellhead units, contributed to premature pressure losses which will reduce the fields' productive lives.

The main cause of higher gas production costs in the future will be West Siberian conditions. During 1971-75 the nationwide cost of 1 meter of production drilling rose from 140 to 210 rubles. Of that increase, 56 percent resulted from moving equipment to new regions, while greater well depths accounted for only 10 percent.[44] With most proved north Tyumen' gas reserves at shallower depths than in older regions, West Siberia's major costs stem from harsh climatic conditions. The desert production environment in Central Asia has also hampered gasfield development, but not to the same extent. West Siberia lacks basic infrastructure required for direct and indirect production support. Roads and railroads are few and, along with other infrastructure, their construction can constitute up to 60 percent of investment in field development.[45] Drilling and production equipment are frequently delivered either slowly by surface or by air, both at

[20] A packer is a rubber annulus, attached to a length of pipe, which can be inserted into a well and expanded to seal off the upper part of the well from the lower. It can be used to permit the extraction of oil or gas from two or more productive strata through separate tubings in the same well (multiple completion). In the case of multiple completion of several gas-bearing strata, packers serve to maintain the integrity of the production zones, each of which may be under different pressure or contain gas of different quality. Separation of the gas from different zones, in this manner, facilitates processing of the gas at the surface.

very high costs. West Siberia's permafrost and tundra place tremendous stress on equipment, labor, and living facilities, reducing productivity and necessitating additional large outlays for infrastructure.

Handling extracted gas in these areas will be another economic burden. Moscow must expand substantially its investment in facilities throughout the USSR for processing of sour gas, gas condensate, and associated gas.[21] Tyumen' Oblast's large reserves of condensate and associated gas will require huge investments in plant capacity. Investment in other equipment for collecting and preparing gas for pipeline transport—such as intrafield pipe networks—will grow substantially as new fields come on stream. The length of pipeline networks for intrafield collection increased by 30 percent during 1970-73 (see table J-19).

The Soviets are prepared to expand the stock of plant and equipment needed to improve their gas production base. They are unlikely, however, to attain targeted returns. The extraction end of the industry has often underfulfilled plans since 1960, in great part because of lags in both technological innovation and field equipment installation. Even where infrastructure has been sufficient, poor management and chronic shortages have repeatedly created supply bottlenecks. The industry will face the same or greater problems in the new producing regions in East Siberia, the Far East, and offshore. Moreover, unless pipeline construction in remote northern areas is hastened, the gap between planned production of gas and actual deliveries to consumers will remain—regardless of the pace of field development.

IV. The Gas Distribution System

The costliest and most trouble-plagued sector of the Soviet gas industry is pipeline transport. Moscow has made great efforts to install a massive network of trunklines[22] and gas storage sites, linking its remote fields with domestic and foreign consumers. Yet, the transport effort has suffered from simultaneous lags in new pipeline construction and chronic underutilization of existing trunkline capacity. As with gas extraction, transport's problems show no signs of easing before the early 1980s.

A. Current Status

The Soviets have already built the second largest gas supply network in the world (see map). Its length is roughly one-fourth of the US system (see table 15), but its construction is nonetheless a major achievement. Since the mid-1950s gas pipeline installation has moved at a fairly rapid pace to exceed 110,000 km of pipe by 1978. The network's length grew by 16 percent per year in 1956-76, but the growth rate was only 8 percent a year during 1971-75, in part because construction increasingly had to contend with arctic and desert conditions (see table J-20). Despite such obstacles, several large gas delivery systems have been built from Tyumen' and the Karakum Desert since the late 1960s (see appendix I).

Average length of transport has grown substantially especially since the late 1960s, reflecting

Table 15

Length of Gas Transmission Pipelines in the USSR and the United States[1]

	Thousands Kilometers		
	USSR	United States	USSR as a Percent of United States
1950	2.3	182.1	1
1955	4.9	234.9	2
1960	21.0	295.8	7
1965	42.0	340.3	12
1970	67.5	406.8	17
1975	99.2	434.9[1]	23
1976	103.5	416.5[1,2]	25

[1]Sources: *Narodnoye khozyaystvo SSSR*, Moscow, various issues; *Basic Petroleum Data Book*. Section XII, Table 2, American Petroleum Institute (April 1977); *Gas Facts*, American Gas Institute (1977), p. 53.

[2] Estimate.

[3] The decline in length of US trunklines is generally due to retiring of some lines where declining gas production has made their further use uneconomical.

[21] Further details on gas processing and refining are given in appendix D.

[22] This paper will discuss only cross-country transmission pipelines, not distribution lines within urban and industrial areas, which by 1978 exceeded 108,000 km (*Ekonomika gazovoy promyshlennosti*, no. 2 (1978), p. 3).

the emerging production roles of Central Asia and West Siberia.[46] The distance of new gasfields from consuming centers now requires lines up to twice the length of major trunk systems built 10 years ago, and Moscow expects the average distance of transport to increase from 1,294 km in 1975 to 1,900 km by 1980.[47] Centralizing control of such long-distance pipeline operations has received high priority. In 1976, 6,300 km of trunkline were automated (6 percent of the trunkline network),[48] and several thousand more kilometers were automated in the early 1970s including telemechanization of compressor station and valve operations.

The increasing costs of transport, due to a doubling of average length of transmission between the early 1960s and 1975, have been partially offset by a greatly expanded use of more economical, large-diameter lines,[23] (see tables 16 and J-21). Large-diameter trunklines accounted for 40 percent of total gas pipeline length in 1975, compared with only 18 percent in 1965. As a result the average pipeline diameter has increased 83 percent during 1961-75 from 553 mm to 1,012 mm,[49] which is roughly twice as large as that of the United States.

Pipeline transport is the gas industry's most expensive sector. It embraces three-fourths of the industry's fixed capital, receives about 60 percent of the industry's annual investment and employs 20 percent of its 200,000-man labor force.[50] Although its share of investment has dropped slightly since the late 1960s—the result primarily of a jump in allocations to extraction—transport will continue to consume the bulk of gas industry resources. New and larger logistical problems of pipelaying and heavy imports of large-diameter pipe and related equipment have required continual and large increases in investment. Fixed capital in trunkline transport more than doubled in absolute terms during 1971-75 while gas production increased by 46 percent.[51] New investment allocations per 1,000–cu m increment of transported gas similarly increased from 36 to 70 rubles in that period.[52]

As a result of these trends average costs for piping gas declined steadily through 1966, and rose sharply in 1971-75.[53][54][24] Inefficient use of pipeline capacity due to lagging completion of new compressor stations (see section B, below) and production declines at older fields are also pushing costs up, as the latter has in the United States. The prospect of continued underuse of capacity is probably a major reason for little Soviet discussion in recent years of building lines of even larger diameter—such as 1,520 mm. The difficulty of manufacturing pipe and equipment for such lines domestically, and the expense of ordering them from the West, is certainly another reason.

Still, Soviet claims of a unified natural gas delivery system capable of maintaining adequate year-round supplies to all major consuming centers are not yet justified. Repeated reports of gas shortages—some of them "serious"—reflect the pipeline-storage network's insufficient capacity and flexibility to handle large demand fluctuations. Substantial increases in storage capacity during the current five-year plan (1976-80) are slated to improve supply reliability for many cities.

As the distance from gasfield to Soviet consuming centers has increased, underground storage facilities for use during winter's peak demand periods have become much more important. And, indeed, gas storage capacity has grown rapidly over the past few years. Storage

[23] Pipe of 1,020 mm or larger. The USSR has become the first country to adopt the widespread use of 1,420-mm pipe, the world's largest diameter.

Table 16

Distribution of Gas Pipeline Sizes

Percent

Diameter (Millimeters)	1960	1965	1970	1975	1980 [1]
1,420	0	0	0	3.6	11.1
1,220	0	0	5.6	15.2	13.5
1,020	3.2	17.8	23.5	20.8	19.3
820	10.8	9.5	7.4	7.1	5.3
720	29.4	24.7	19.1	15.2	10.6
Other	56.6	48.0	44.3	38.1	40.2

[1] Estimate.

[24] Cost data for 1967-70 are unavailable.

sites grew from only four in 1960 to 25 in 1975, raising total storage capacity from 0.7 billion cu m to 39.5 billion. Ten facilities were built during 1971-75 alone (see appendix E).[55] Almost all of them are near the largest cities in the European USSR. The primary improvements in distribution, however, must still come in the pipeline network itself, where expansion efforts thus far have run into several serious problems.

B. Pipeline Construction Problems

The Soviet gas industry has consistently failed to meet production goals, primarily because trunklines to newly opened fields either were not completed on schedule or were operating at below capacity. Such failures stem from several basic problems:

(1) The increasing length of pipelines and the need to construct them under adverse climatic conditions.

(2) Inadequate capacity to produce and install rapidly large diameter pipe and powerful compressors.

(3) Shortages of skilled manpower, machinery, and materials for pipeline projects and poor management of available resources.

The pace of trunkline construction has held close to plan during the 1970s. Over 30,000 km of pipe were laid during 1971-75, meeting the five-year plan.[56] Compressor station completions in that period increased by 156, against 85 new stations built during 1966-70.[57] Although total compressor station power increased sharply in 1973-75 (see table J-23),[25] use of aggregate trunkline capacity has rarely risen above 90 percent of the maximum potential (see table 17).[26] On several major lines in 1975, use was only 66 percent of capacity (see table 18).

[25] By 1977, more than 70 percent of on-line compressor capacity was generated by gas turbine drive—as opposed to piston drive—and electric power sources. Turbine units are more efficient and have larger capacities than other forms of gas line compressors. Robert Campbell, *Recent Trends in the Soviet Oil and Gas Industry*, Baltimore (1976), pp. 56-57.

[26] This performance is similar, however, to that in the United States.

Conditions surrounding trunkline construction are unlikely to improve. Along with greater length will come an increase in the number and severity of natural obstacles. West Siberia's burgeoning pipeline network is being installed in regions of tundra, permafrost, and swamps, where adverse weather and ground conditions limit pipelaying to only a few months of the year. The large Central Asia–Center system covers thousands of kilometers of desert. The Orenburg pipeline will cross more natural and manmade obstacles than have most Soviet lines in the past. Lack of roads, housing, and established supply and repair bases—particularly in Tyumen'—

Table 17

Use of Gas Trunkline Capacity [1]

	Billion Cubic Meters		Percent Use of Capacity
	Capacity	Use	
1967	150.7	143.3	95
1968	182.8	155.1	85
1969	185.8	166.0	89
1970	235.7	181.5	77
1971	244.1	209.8	86
1972	244.1	219.9	90
1973	261.1	231.1	89

[1] Source: Khaskin, *Osnovnyye fondy*, p. 47.

Table 18

Use of Capacity of Selected Gas Trunklines, 1975 [1]

Trunkline	Billion Cubic Meters		Percent Use of Capacity
	Maximum Capacity	Use	
Total	**237.8**	**158.0**	**66**
Medvezh'ye-Nadym	60.0	31.0	52
Nadym-Punga	56.0	40.0	71
Punga-Northern Lights	42.0	30.0	71
Urals system	20.0	15.5	78
Nadym-Punga-Gor'kiy-Center	17.3	14.5	84
Central Asia-Center Nos. 3 & 4	42.5	27.0	64

[1] These lines were cited by the Soviets as examples of underutilization due to lagging installation of compressor capacity. Source: R. D. Margulov, et al., *Razvitiye gazovoy promyshlennosti i analiz techniko-ekonomicheskikh pokazateley*, Moscow (1976), p. 46.

slow construction considerably. Efficiency of Soviet logistical organization, perennially low in good conditions, deteriorates further in remote areas and can delay some projects for months. Several trunklines, including the Northern Lights and Messoyakha-Noril'sk systems, have suffered breaks from stress caused by cold and the buckling of the ground from repeated freezing and thawing.[58] Installing some pipe sections aboveground on berms and trestles has reduced the problem but has not eliminated it. High winds, for example, have continued to shake the lines, chafing insulation and in some cases toppling pipe from the supports, causing it to break. Poor-quality pipe insulation has led to breaks in swampy and desert regions as well as in permafrost.

Inadequate technology and capacity in support industries have particularly hindered the delivery system's development. A major problem for the rest of the decade is a shortage of domestically manufactured large-diameter pipes and valves of high metallurgical quality needed to withstand Siberian cold and internal corrosion. Pipe and valve imports have solved part of the problem, but Moscow wants a larger domestic production capability,[59] particularly to reduce hard currency outlays on imports of large-diameter pipe.

The Soviets must, in addition, improve gas processing capacity in both Central Asia and northern Tyumen' to reduce the amount of corrosive gas entering trunklines. This problem has particularly plagued Central Asia's large pipeline systems. [60] Welding technology on most lines under construction also lags behind the developed West, causing both delay in pipelaying and pipeline breaks during operation. Soviet inability to produce compressor station components in adequate number and quality is another major weak spot. Moscow has made substantial imports of compressor equipment, but the total supply of units for large-diameter lines is still short.

Faced with these natural and technical obstacles, the Soviets have tried to accomplish more than their limited resources allow. Trunkline capacity has frequently fallen short of plan, in great part because manpower, machinery, and materials have been spread thinly among many projects. Both oil and gas lines compete for the same labor force, and only a few projects receive adequate allocations. Emphasis on putting northern Tyumen' gasfields onstream clearly has given priority to expanding the region's major pipeline systems—Northern Lights, Urengoy-Chelyabinsk-Center, Urengoy–Nizhnaya Tura–Center. Even so, Moscow has not had enough skilled manpower or advanced equipment in recent years to finish on time all the routes and compressor stations that it has planned for those areas.

V. Trade

Rapid growth in natural gas production is paralleled by the increasing importance of gas to Soviet foreign commerce. Soviet net exports of gas will rise from 7 billion cu m in 1975 to approximately 40 billion cu m in 1980, and hard currency earnings in 1977 prices will jump from $200 million to well over $1 billion. But Soviet imports of gas will also increase beyond 1980, limiting growth in 1981-85 of net gas exports.

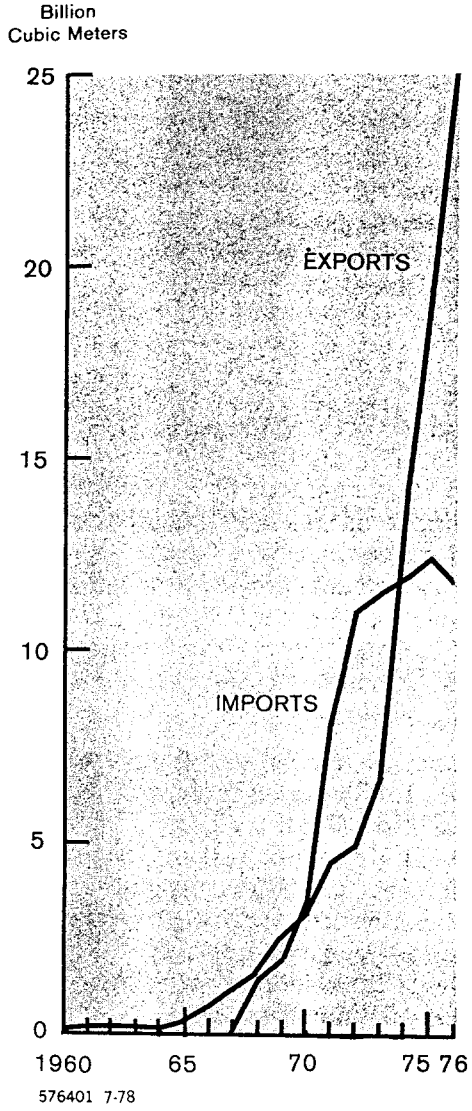
Natural gas has only recently become an important Soviet export. During the early 1960s, USSR gas trade—while composed entirely of exports—was inconsequential (see figure 8 and table J-24). [61] The export volume did increase in the latter half of the 1960s, and in 1970 was more than eight times the level of 1965. It was still fairly small, although larger than the volume of imports from Afghanistan, which began in 1967. With the addition of imports from Iran, the Soviets became net importers in 1970-73. [27]

Not until 1974 did the USSR finally emerge as a substantial international gas supplier. Total exports to Eastern and Western Europe almost tripled in 1974-75, giving the Soviets net exports of 2.1 billion cu m in 1974 and 6.9 billion cu m in 1975. Deliveries to Western Europe were made mostly through gas-for-pipe compensatory arrangements. The export volume in 1976 was 25.8 billion cu m, 66 times larger than that of 1965,

[27] Imports were made via a pipeline built from Iran to the Soviet border. See section B, below.

Figure 8

USSR: Natural Gas Trade



and the value of exports also climbed from 2.7 million rubles in 1965 to 733.4 million rubles in 1976. [28] Of those receipts, hard currency earnings from Western Europe constituted an increasing share beginning in 1974-75, jumping from nearly $30 million in 1973 to $346 million in 1976. Despite the USSR's brief stint as a net importer in physical terms, it never experienced a deficit in net earnings. The ruble value of imports grew from 14 million in 1970 to 176 million in 1976.

[28] At the respective official ruble-dollar exchange rates for those years, the dollar values would be $3 million (1965) and $972 million (1976).

A. Exports

Eastern Europe has received the bulk of Soviet gas exports thus far and will continue to do so.[62] Until 1968, European members of CEMA [29] were the sole recipients of the USSR's exports and during 1960-75 took 67 percent of the gas shipped beyond the Soviet border. That percentage is likely to drop to about 55 percent during the last half of the 1970s, and will probably hold to at least that level through 1985.

Substantial exports to Eastern Europe began in the early 1970s.[63] The USSR had exported small amounts of gas to Poland since the late 1950s, but it was only after completion of the first *Bratsvo* (Brotherhood) trunkline to Czechoslovakia in 1967 and full development of Ukrainian gas production that exports to Eastern Europe began to expand substantially (see table J-25). In 1973-75, Bulgaria, East Germany, and Hungary became importers, and exports to Czechoslovakia and Poland increased as the *Bratsvo* line's capacity was raised and its length extended to other East and West European countries and as new lines were built. The substantial growth in exports to both East and West began at that point.

By the early 1980s, Soviet gas supplies to Eastern Europe will have doubled over current levels (see table J-26). Additional East European demand will be met partly by further expansion of the *Bratsvo* trunkline, which will handle gas from the Ukraine, Central Asia, and West Siberia. Most of the increase, however, will come from the Orenburg pipeline, scheduled for completion in late 1978 (see appendix F). Stretching 2,750 km from the newly developed Orenburg field to the Czechoslovak border, the line is to deliver 15.5 billion cu m to the five current CEMA customers plus Romania. Although the line, being partly constructed and financed by

[29] The Council for Mutual Economic Assistance. Its European members are Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, and Romania.

the six importers, probably will not reach full capacity until well after 1980, it still should permit a doubling of total Soviet exports to those countries by 1981. Yugoslavia will also begin receiving up to 3 billion cu m of Soviet gas in the early 1980s via Czechoslovak and Austrian lines.[64]

As a result, the Soviet-supplied share of total East European imports will rise from 96 percent in 1975 to almost 100 percent by 1980, when it could be satisfying almost 40 percent of all East European gas requirements. Bulgaria and Czechoslovakia are (see table 19 and table J-27), and will continue to be, almost totally dependent on the USSR for gas supplies.

Western Europe is a newer but far more important market for Soviet gas. Increases in both demand and price in Western Europe will make gas a substantial hard currency earner in the late 1970s. By 1980 Soviet annual gas earnings could exceed one-half of the hard currency earnings anticipated from the export of crude oil and oil products in that year. The increase in hard currency receipts during 1974-76 reflected both a doubling of prices (from $15 per 1,000 cu m in 1973 to $30 per 1,000 cu m in 1976) and a quintupling of the volume of gas exports to West European customers (see table 20).

Austria, benefiting from a branching of the *Bratsvo* line, became the first Western importer in 1968. As growth of Soviet gas production in the late 1960s raised both Soviet export capacity and the need for gas-related equipment and pipe

Table 19

Natural Gas Exports to Eastern Europe
as a Share of East European Gas Consumption

Percent

	1965	1970	1975
Total	2	6	18
Bulgaria	0	0	100
Czechoslovakia	0	64	83
East Germany	0	0	29
Hungary	0	0	10
Poland	23	17	31
Romania	0	0	0

imports from the West, Moscow began a more substantial penetration of the West European gas market. During 1969-76 the Soviets concluded several trade agreements, most of them involving exchanges of gas for large-diameter pipe and ancillary equipment on credit. The majority of these agreements provide for continued deliveries of Soviet gas beyond 1990.[65] During 1973-74 West Germany, Italy, and Finland began receiving gas deliveries; France became an importer in 1976.

Under contracts signed before 1977, Soviet exports to Western Europe will triple in the last half of the 1970s, reaching 25 billion cu m by 1980. That amount will represent an estimated 19 percent of all gas supplies of those West European nations *receiving* Soviet gas. In caloric terms, Soviet gas exports to Western Europe in 1980 will equal more than 50 percent of probable Soviet oil imported by that region. Exports

Table 20

Net Exports of Oil and Natural Gas [1]

	Oil [2]			Gas		
	Million Metric Tons	Million b/d	Hard Currency Earnings (Million US $)	Billion Cubic Meters	Million b/d Oil Equivalent [3]	Hard Currency Earnings (Million US $)
1970	93	1.9	405	− 0.3	Negl.	13
1975	123	2.5	3,180	6.9	0.1	223
1976	148	3.0	4,500	14.0	0.2	346

[1] Source: *Vneshnyaya torgovlya SSSR* (1970, 1975, and 1976).
[2] Including oil products.
[3] One billion cubic meters of gas equals 16,800 b/d oil.

through 1985 will increase by at least another 40 percent under an arrangement concluded with West Germany, Austria, France, and Iran in early 1976 (see appendix G). [30] Up to 23 percent of total gas supplies of countries importing Soviet gas would be furnished by those Soviet exports.

Further deliveries during 1981-85 under additional contracts are possible, although the amounts are difficult to determine. If USSR gas supplies cannot meet demand in both Eastern and Western Europe, for example, the Soviets probably will give priority to East European customers to forestall political and economic disruptions among the East European partners. Expansion of exports to Western Europe much beyond current contract levels then will be less likely. Joint ventures in liquid natural gas (LNG) exports with Western Europe, Japan, and the United States would also expand Soviet export revenues. However, LNG deliveries will not begin until the late 1980s or early 1990s at the earliest, even if contracts are consummated within the next year, which is unlikely (see appendix H).

B. Imports

Soviet gas imports will remain fairly stable through 1980, with Afghanistan and Iran remaining the USSR's sole suppliers. Imports rose sharply in 1970-72 from initial deliveries through the 1,200-km Iranian-Soviet trunkline, stretching from the Ahwaz gasfield to the Soviet border town of Astara in the Transcaucasus. Imports from that line—currently about 10 billion cu m a year—so far have been made on a barter basis. During the current Five-Year Plan (1976-80) they should increase by only 18 percent.

Afghanistan, which became the first gas exporter to the Soviet Union in 1967, pipes almost all of its production to Central Asia for local Soviet consumption. The Soviets have assisted Afghanistan in expanding its production and transport capacities and will continue to do so during 1978-80. [66] Consequently, Afghan exports to the USSR will probably increase moderately in the early 1980s.

Iran has provided the bulk of Soviet gas imports since 1971 and will do so for the next decade. Almost 10 billion cu m of Iranian gas is delivered annually through the 1,200-km trunkline entering the USSR at Astara in the southern Caucasus, [67] and this level may rise slightly during the next four years. Soviet imports from Iran will double by 1985, however, under a trilateral switch deal. The Soviet Union will import an added 17 billion cu m annually from Iran for use in gas-poor Soviet regions and will pipe a slightly smaller amount of Soviet gas to the three West European consortium members and to Czechoslovakia. [68] The increase will negate much of the expected volume gain in USSR exports during that period, but the reexport to Western Europe may provide considerable net hard currency earnings for Moscow (see appendix G).

VI. The Need for Western Assistance

Gas production—like output in most other sectors of the Soviet economy—is to grow during the Tenth Five-Year Plan primarily through increased productivity of labor and capital. [69] [31] How much productivity does increase, however, will depend greatly on technological improvements. Repeated calls for a "technical reequipping" [70] of the industry reflect serious Soviet weaknesses in several areas, many of which have been or could be partly alleviated by purchases of Western equipment and technical assistance.

A. Pipelines

The USSR cannot produce all the high-quality, large-diameter pipe and valves needed for expansion of the pipeline systems linking Tyumen' with the Western USSR. [71] Poor-quality equipment for welding and weld-testing is a related shortcoming. [72]

[30] By 1980 Soviet gas exports' share of total gas supplies of all Western Europe could reach 9 percent and by 1985, 11 percent. On the other hand, Soviet gas deliveries will constitute only 2 percent of total Western European energy supplies in 1980 and 3 percent in 1985.

[31] The Gas Ministry expects labor productivity increases in gas extraction (33 percent), gas processing (47 to 48 percent), and pipeline transport (9 percent). See *Gazovaya promyshlennost'*, no. 11 (1976), p. 4.

Consequently an increasing share of Soviet imports involves pipeline-related items. Much of the large-diameter, high-quality steel pipe used in gas lines constructed since the late 1960s has come from Western Europe—Austria, West Germany, Italy, and France in gas-for-pipe deals—and from Japan. During 1971-75 the USSR spent more than $4 billion on 6 million tons of large-diameter pipe, [73] at least 5 million tons of which probably went for gas lines.[32] Imports of gas-related equipment reached roughly $1 billion in 1975—about 7 percent of total Soviet hard currency imports. [74] Pipe again constituted most of the bill. Imports of large-diameter gas pipe, mostly 1,420 mm, may reach 8 million to 10 million tons in 1976-80, the current five-year plan period. [75]

B. Compressor Stations

The Soviets through the early 1980s will not be able to manufacture enough turbines and high-capacity compressor units (for example, 25 megawatts) [76] to provide required pressure in the West Siberian pipeline system. Lack of unit standardization [77] permitting rapid repair or replacement is a major problem.

Gas turbine and compressor purchases have risen in recent years, with more than $1 billion spent during 1972-76 for 3,000 MW of capacity [78]—the equivalent of almost 40 percent of total Soviet compressor capacity in 1975.[33] Moscow may order up to 10,000 MW of additional compressor power by 1980, most of which would be placed on the northern Tyumen' pipeline systems. [79] In 1976 the Soviets signed two contracts calling for delivery in 1977-78 of equipment having a total capacity of almost 2,000 MW:

- A 158-unit deal for 22 compressor stations on the Orenburg pipeline—to be built by AEG Kanis (Mannesmann) of West Germany and Italy's Nuovo Pignone (ENI) for approximately $1 billion. [80]
- An agreement providing 42 units for six compressor stations on the Urengoy-Chelyabinsk line—delivery by a US-UK consortium for $166 million. [81]

C. Gas Processing

Many gasfields lack sufficient capacity to collect gas of high temperature or under extreme pressure; to process associated gas or gas with sulfur, condensate, or other properties; or to provide initial compression for transport of high-volume output. [82] To boost Soviet gas processing capability Moscow has ordered at least three processing plants for West Siberia. [83]

D. Well Drilling and Completion

The Soviets will remain interested in purchasing Western drilling equipment such as rigs, drill pipe, and well casing material, plus wellhead assemblies and equipment for completing wells that exploit several gas-bearing strata simultaneously.

E. Exploration

Effective seismic equipment and digital field computers are not widely available to Soviet exploration teams.[84] Soviet technology in this area is well behind that in the West and usually is not adequate for accurate mapping at 5,000-6,000 meters in Turkmen, the Ukraine, and Komi ASSR or in the permafrost of Siberia and the Far East. The Soviets in the past few years have shown increased interest in obtaining Western seismic mapping equipment.

F. Offshore

Soviet experience in all phases of offshore petroleum production has been limited mainly to the shallow portions of the Caspian and Black Seas, where expansive networks of piers, trestles, and manmade islands have been used instead of floating drilling platforms.[85] Floating platforms, subsea completion equipment, and related technology needed for exploration and development operations in deeper waters of the Kara Sea and elsewhere pose requirements that exceed current Soviet production capability. Even West-

[32] Soviet trade figures for large-diameter pipe imports include pipe of sizes ranging from 530 mm to 1,420 mm.

[33] Most of the units purchased during 1972-76 were not installed by the latter date.

ern firms have not yet manufactured offshore rigs capable of working in the hazardous waters off northern Siberia. A few Western-designed offshore drilling rigs have been purchased for use in the Caspian Sea, but major imports of offshore technology needed for operations in arctic waters probably will not occur for several years.

VII. Prospects

The outlook for Soviet gas production is relatively bright compared with that for oil output, which is expected to peak in the early 1980s. Proved-plus-probable reserves of 28 trillion cu m would provide 80 years of output at the 1977 rate of 346 billion cu m. In contrast, US reserves of 6.2 trillion cu m would supply only 11 years of output at the 1976 US rate of 565 billion cu m. Moreover, Soviet reserves are likely to expand by several trillion cu m over the next decade. Although there remains substantial uncertainty, annual growth in gas production can reasonably be expected to average about 6 percent during the Tenth, Eleventh, and Twelfth Five-Year Plans which cover the 1976-90 period (see table 21). That the gas industry may fail to meet a particular annual or five-year plan goal—as is likely in 1976-80—is not of central importance to longer term Soviet energy planning. Of greater importance is the fairly steady rate of growth that can be expected over at least the next 10 years.

Natural gas will not, however, solve Soviet energy problems. Gas export earnings by the mid-1980s may make gas the Soviets' leading hard-currency export, but technical problems will prevent gas from soon being substituted widely for oil in the domestic economy. More important, if difficulties facing the gas industry are not overcome within the next few years, not even West Siberia's large gas reserves will be able to guarantee continuous production growth beyond 1985. Two basic problems will affect development of the gas industry during the Tenth Five-Year Plan and beyond: (a) rapidly falling production at older fields and (b) persistent bottlenecks hindering expansion of Siberian output.

Table 21

Projected [1] Gas Production

	Billion Cubic Meters	Average Annual Percent Growth
1975	289	
1980	415-420	7.5-7.8 [2]
1985	560-600	5.9-7.7 [2]
1990	700-730	3.1-5.4 [2]
1976-90		6.1-6.4

[1] CIA projections.
[2] Five-year period.

A. The Tenth Five-Year Plan (1976-80)

Gas production during 1976-80 is planned to rise by 50 percent—or at an average annual rate of 8.5 percent—reaching 435 billion cu m in 1980. To do so, the gas industry will have to improve its performance in several areas (see table 22). Of primary importance is the addition

Table 22

Planned Growth of the Gas Industry During the Tenth Five-Year Plan [1] 1976-80

	1975	1980 Plan
	Billion Cubic Meters	
Production	289	435
Gas storage [2]	18	45
Natural gas processing	22	32
Associated gas processing	29	40-45
Exports	19	59 [3]
Imports	12	15 [3]
Apparent consumption	282	391 [3]
	Thousand Kilometers	
Transmission pipelines	99	135
	Units	
Compressor stations	286	586
	Billion Rubles	
Capital investment [4]	11	19

[1] Sources: *Gazovaya promyshlennost'*, no. 3 (1976), pp. 1-3; no. 11 (1976), p. 12; and no. 8 (1977), pp. 2-6; *Ekonomicheskaya gazeta*, no. 6 (1977), p. 2.
[2] Volume of recoverable gas in storage.
[3] Estimated.
[4] Including pipeline transmission systems; total investment for 1971-75 and 1976-80.

of 35,400 km of the trunk pipeline system—much of it to be 1,420-mm pipe.[34] Successful completion of a massive compressor station construction program will prove equally important, since below-plan installation of compressor capacity would prevent the trunkline system from handling the high level of gas output planned for 1980. Pipelines and compressors accordingly will consume most of the record 19 billion rubles of investment allocated to the the industry in the Tenth Five-Year Plan.

None of these goals is easily achievable, however, and nationwide gas production probably will not reach the upper limit of the 1980 plan—435 billion cu m—primarily because installation of pipeline compressor stations will continue to lag. Supply of large-diameter linepipe probably will not pose a major problem, with substantial imports of pipe already contracted for making up most or all shortfalls in domestic manufacture. The principal bottleneck will be inadequate capacity on the three lines scheduled to move gas from northern Tyumen' to the European USSR. Under apparently intensive development, Urengoy, Medvezh'ye, and smaller neighboring fields probably will reach their planned aggregate capacity of 139 billion cu m by 1980.[35] Construction of the first Urengoy-Chelyabinsk line will have been completed before that time, but full completion of additional lines on the Northern Lights and Urengoy-Center systems—the other two lines to serve Tyumen'—is less likely. Moreover, Soviet delays in negotiating imports of Western compressors, long leadtimes for the manufacture and delivery of imported units, and lagging Soviet installation of the units will allow perhaps only 120 billion to 125 billion cu m to be moved—15 billion to 20 billion cu m below plan. The Soviets themselves have indicated concern with these problems by having long retained the range of 400 billion to 435 billion cu m in the 1980 plan. One Soviet publication in early 1977 cited the plan as 435 billion cu m [86] but the Gas Ministry reintroduced the range later in the year.[87]

Moreover, as indicated above, Moscow has planned for a certain loss in output from the older fields of the European USSR and Central Asia during the last half of the 1970s, while investing heavily since 1970 to minimize the amount of that loss. A precise projection of the reduction in output is difficult. An aggregate Ukrainian gas production plan for the current Five-Year Plan of 1976-80, however, indirectly indicated that output there could drop from 69 billion cu m in 1976 to roughly 50 billion cu m by 1980 rather than the 59 billion cu m planned earlier (see appendix A).

B. The 1980s

How fast gas output increases will depend heavily on the priority it receives. If a decline in oil production and continued sluggish growth in coal extraction prompts greater Soviet demand for gas for domestic use and export, Moscow may expand 1981-85 investment well beyond the 19 billion rubles planned for 1976-80. Most new investment will probably go to northern Tyumen'. Given resources sufficiently greater than the estimated 15 billion rubles allocated to Tyumen' field and pipeline development in the last half of the 1970s, [88] several major deposits—notably Yamburg, Zapolyarny, and possibly Kharsavei on the Yamal Peninsula—could be developed simultaneously. Equally important, major new pipelines could be constructed to link the fields with existing Northern Lights and Urengoy-Center systems. Such an effort, combined with Urengoy's attainment of a possible peak capacity of 100 billion cu m in the early 1980s, [89] could result in 1985 production levels at the upper range of the 560 billion to 600 billion cu m projected in this paper.

Output much beyond that range, however, is unlikely. Infrastructure shortcomings and permafrost conditions will prove worse at the new fields than at Urengoy and Medvezh'ye. These

[34] This can be compared with 31,700 km of pipeline laid in 1971-75 and equals the total length of gas trunkline laid in the United States between 1968 and 1976. Pipe of 1,420-mm diameter is the largest pipe in substantial use in the world. At proper pressures it allows large volumes of gas to be transported at costs lower than those for transport of similar volumes in smaller pipes.

[35] The remainder of the 155 billion cu m planned for Tyumen' Oblast in 1980 will come primarily from associated gas production at the region's major oilfields. That output will move southward via the Nizhnevartovsk-Kuzbass line, essentially completed in late 1977, which should reach full capacity by 1979. *Gazovaya promyshlennost'*, no. 3 (1977), p. 6.

two factors will plague field development and pipelaying and may limit additions to production capacity regardless of the amount of resources expended. Only if intensive development of the remaining large deposits begins before 1980—which is unlikely—would any crash effort bring more than one of the fields and its pipelines up to full capacity by 1985. More likely, Yamburg and Zapolyarny will both begin production by that year at partial capacity. Kharsavei and other fields probably will not contribute to output until the late 1980s.

Production growth throughout the 1980s probably will be constrained by West Siberian bottlenecks and by declining extraction at aging fields elsewhere in the USSR. Currently at least 100 of the USSR's 300 producing gasfields have passed peak production, [90] and this proportion will rise substantially in the 1980s. Intensive extraction efforts may slow the rate of decline in production through 1980. By the early 1980s, however, the Ukraine, all of Central Asia, and some Tyumen' fields will experience major drops in output, forcing new Siberian fields to cover growing losses of capacity before contributing to net increases in national production. Yet constraints on Tyumen' gas production will limit that region's ability to fulfill both those tasks. As a result, Soviet gas output may rise to only around 700 billion cu m in the late 1980s. A virtual leveling off of production at that point is possible, although a decline is unlikely.

C. Continuation of Rising Costs

Development of the Tyumen' gas industry will substantially raise the cost of Soviet natural gas extraction and transport during the 1980s. A massive investment campaign to develop several giant Tyumen' deposits will increase the pace of production but will lower the ratio of output to capital even further. Continued heavy investment in infrastructure will contribute to rising gas production costs. A major acceleration in pipeline and compressor station construction would lead to even higher costs per unit and result in low returns. During the 1980s the Soviets' ability to solve pipeline-related problems, particularly compressor manufacture and installation, could improve considerably. Increased purchases of Western equipment and assistance (see the next paragraph) or improved and expanded production of Soviet compressor models would facilitate enlargement of pipeline capacity. How far the Soviets will move in this direction in the 1980s, however, remains unclear. Outside Tyumen', continued heavy investment to maintain output in fields with declining extraction rates similarly will raise industry costs. The Ukraine will prove a particular drain through the early 1980s, as may Uzbek and Turkmen.

Western assistance possibly could bolster the effectiveness of gas industry investment. US, European, and Japanese aid in pipeline installation, drilling, and gas processing—as well as exports of related materials and equipment—might permit more rapid and efficient utilization of investment in a stepped-up Tyumen' development drive.

D. Reliance on the West

The Soviet gas industry indeed will remain dependent on imports of Western equipment into the 1980s. If the remaining large gas deposits at Tyumen' are developed roughly one at a time, gas-related import requirements may not greatly exceed those for the Tenth Five-Year Plan (1976-80). If the pace is substantially increased, the Soviets will probably expand equipment imports. In this case direct Western technical assistance in field development and pipeline construction would be helpful, but past Soviet reluctance to allow on-site Western participation makes this unlikely. If Moscow launches a major effort to find and develop reserves in the arctic seas north of West Siberia, Western equipment will almost certainly be required. Most additional imports of pipe will probably be made through gas-for-pipe compensation agreements with West European firms. Gas deliveries over several years will be required to pay for the pipe and other equipment obtained, but increases in the price of exported gas could reduce the timespan.

Soviet ability to purchase all the needed Western gas-related imports and assistance, however, may well be constrained, particularly if, as is

likely, oil export earnings fall sharply in the early 1980s. Moreover, even Western help may prove unable to solve substantially or rapidly the massive problems facing large-scale development of a wilderness region until the infrastructure—particularly transportation—is vastly improved. A stronger Soviet ability to assimilate advanced technology—whether Western or domestic—is also essential for significant improvement in returns on capital.

E. Stepped-Up Campaign

Moscow's concern over the pace of Tyumen' gas development does appear to have grown during the past year. Correspondingly, the Soviets have shown signs of stepping up their campaign to open the region's giant gas deposits.[36] Since mid-1977, Soviet press articles criticizing slow or sloppy handling of pipeline and field construction projects have increased in number and frankness. Major stories in *Pravda, Izvestiya,* and other major papers have aired complaints regarding those problems as well as the basic lack of infrastructure needed for industry support.[91]

The December 1977 plenum of the Central Committee of the Communist Party apparently launched a drive to improve the situation.[92] Budgetary allocations to the Gas Ministry reportedly have been increased—along with those to the Oil Ministry—beyond the amount originally provided for in the 1976-80 plan.[93] Additional men and equipment have already been transferred to Tyumen'.[94] In effect, Moscow appears to be shifting resources from older gas-producing areas to West Siberia, where it calculates that returns on investment will prove higher.

It is unclear whether the new program represents an effort of sufficient magnitude to be termed a crash campaign. Some objectives of the current Five-Year Plan, such as the Urengoy-Chelyabinsk pipeline, have been rescheduled for rapid completion.[95] Yet the commitment to the massive and sustained effort required to develop several giant fields and related pipeline systems simultaneously in the early and mid-1980s—instead of one at a time—is not yet evident. Unless the new emphasis on Tyumen' development results in the widespread resolution of infrastructural, technical, and organizational problems, the extra resources will probably not produce much more gas over the next several years than would be produced without them. Indeed, if the Tyumen' campaign induces increased competition for budgetary resources between the Oil and Gas Ministries, the latter's Tymuen' program may be curtailed. Moreover, transfer of resources from older gasfields, especially those in the Ukraine, will ultimately force output there to drop even faster, undercutting part of the additional increment in Tyumen' output that the stepped-up campaign will induce.

F. Not a Panacea

Because of the likely outcome of developments discussed above, natural gas will ease but not solve expected Soviet energy problems in the 1980s. It will provide the Soviet energy balance with a relatively fast-growing source of fuel and raw materials, in fact approaching or exceeding crude oil production in caloric terms by 1985.[37] Gas will only be able to substitute for oil in some of its uses, however. Most opportunities for easy substitution of gas for oil have already been exploited. Some additional gas production will go for use in industrial boilers and to industrial sectors which are already large gas consumers and in which gas is being substituted for fuels other than oil. Gas consumption will continue to increase substantially in the chemical and metallurgical industries, where it has been replacing coal and coke. Household use will also increase, but will not involve gas-for-oil substitution, since oil has not generally been used directly for heating purposes.

Although substantial conversion could occur in electric power generation, where oil-burning thermal power plants can switch more readily to

[36] The campaign also applies to the Tyumen' oil region. See *Sotsialisticheskaya industriya'* (22 January 1978).

[37] Oil production in 1985 probably will be between 8 million and 10 million barrels per day. Output of natural gas probably will fall within the range of 560 billion to 600 billion cu m, equivalent to about 9.4 million to 10.1 million b/d of oil. See *Prospects for Soviet Oil Production, op. cit.*

gas than to coal, no such shift is apparently intended for the plan period ending in 1980. Indeed, planners actually intend to reduce the share of gas in total fuel consumed by thermal power plants during this period.[96] [38]

Additional industrial sectors can also switch to greater gas consumption in the 1980s. Given declining oil output and an official intent to minimize reliance on foreign energy sources, Moscow undoubtedly will attempt to use gas more widely.

The Soviets currently show no signs of initiating the large-scale substitution campaign that would be required. The nature of significant substitution within individual industrial sectors is not clear, and further research is needed to determine the amount of oil-for-gas substitution possible for each industry within a period of five or 10 years. If historically long Soviet leadtimes characterize such an effort, a widespread shift to gas could be delayed until the late 1980s. Also unknown is the resource allocational priorities that the Soviets would be willing to assign to a major substitution effort and the extent of the technical difficulties they would face.

Internationally, hard currency earnings from natural gas exports to Western Europe will grow substantially. Western Europe is increasing gas consumption and diversifying its import sources, assuring an expanding market.[97] Demand for Soviet gas could be moderated through the early 1980s by new European gas sources—primarily North Sea supplies—and by trade agreements with Algeria and other gas-producing countries. Supply of Soviet gas for export could be constrained occasionally by lagging development of Soviet field and pipeline capacities and possibly by additional gas export commitments to Eastern Europe.

Nevertheless, gas export earnings ultimately should equal the hard currency receipts attained by export of oil. Earnings of $1 billion (in 1977 prices) by export of gas in 1980 will surpass neither the $4.5 billion obtained in 1976 from exports of oil nor the potential earnings of $2.7 billion from oil exports in 1980. By 1985, however, gas will have emerged as a leading foreign exchange winner, with gross hard currency receipts of $2 billion (in 1977 prices) likely. The Soviets meanwhile could be making hard currency outlays for net imports of oil unless, as is unlikely, a successful gas-for-oil substitution campaign at home frees oil for continued export. The importance of gas to future Soviet trade is, therefore, substantial. At the very least gas will provide a large portion of the USSR's purchasing power to cover the rising costs of Western technology and equipment that its gas industry's expansion in the 1980s will require.

[38] Several oil-burning plants in the European USSR could make the switch in the 1980s if a domestic oil shortage required it. However, gas storage capacity near these plants would have to undergo substantial expansion to avoid winter gas supply shortages due to the seasonal peak in demand.

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APPENDIX A

THE OLDER FIELDS

How much the older gas-producing regions in the North Caucasus, the Ukraine, and the Urals-Volga region [39] support future growth of Soviet gas output will depend on how rapidly their contribution declines. After 20 years of extensive exploitation these areas are suffering from problems typical of aging gasfields:

- Steadily diminishing reserves.
- An absolute drop in production.
- Rising production costs.

The reserves situation in the Ukraine and the Caucasus, already poor in the early 1970s, will grow much worse. With the principal deposits developed, exploration teams are faced with the need to locate potentially much smaller ones at great depths (4,000-6,000 meters) in complex geological structures.[98] The results so far in the 1970s have not been good (see tables 8 and 12). Exploratory drilling in the most promising areas—such as the Ukraine's Dnepr-Donetsk and Carpathian basins and the Chernolesskiy region in the Northern Caucasus—has borne little fruit.[99] Inaccurate seismic mapping of deep structures has led to drilling a large number of dry holes.[100] Exploratory drilling itself has lagged because of the lengthy downtimes of drilling rigs. Gas exploration rigs in the Ukraine were idle more than 70 percent of the time as a result of technical problems in drilling and a lack of supplies.[101] The few fields that have been opened since the late 1960s for the most part do not have more than 10 billion cu m of reserves (A + B + C_1). However, offshore exploration in the Caspian and Azov Seas may increase reserves slightly in the 1980s.

With expensive exploration efforts showing little return, gas production associations will attempt to maintain current output levels at existing fields. By drilling new production wells to deeper gas-bearing strata and increasing extraction from currently exploited zones, the Soviets probably hope to stabilize output at least through 1980. Thus, even if reserves by that time are near exhaustion, the old fields may avoid a drastic shortfall that would hold national production below the 1980 goal. The Soviets are particularly counting on minimizing the Ukraine's decline.

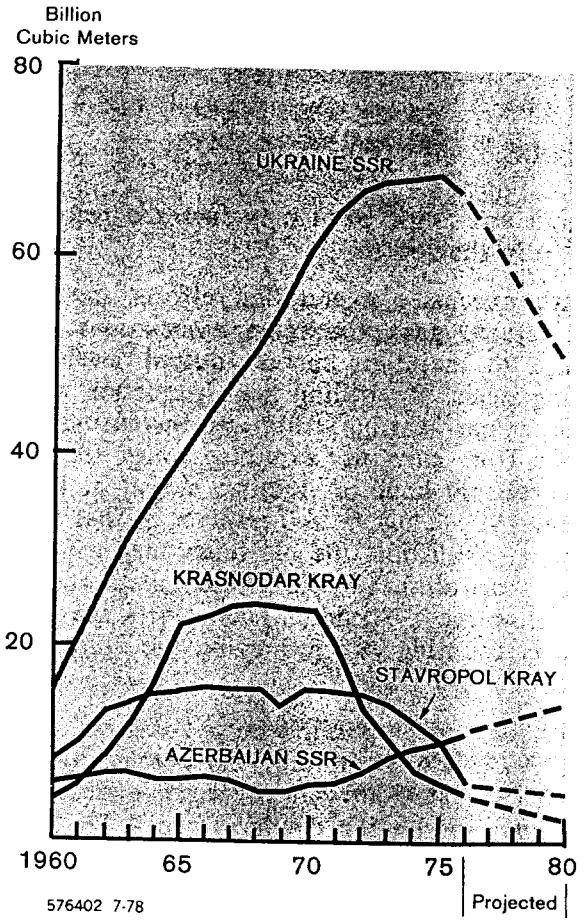
Although the republic's output did not peak until 1975, it grew at only 2.4 percent a year during 1971-75. Following the region's success in averting a production decline forecast by Moscow for 1976, the Ukraine's projected 1980 production was raised to 59 billion cu m [102] from 53 billion cu m.[103] At the higher level, it would fall 14 percent below 1975—not low enough to detract substantially from West Siberia's growth.

A sharp drop in Ukrainian production might be averted for the next year or two. By the early 1980s, however, the older regions as a whole will have experienced a substantial decline (see figure A-1). Gas from the Caucasus, even with some offshore production, will constitute less than 5 percent of national production by 1980. The Soviets will continue intensive development drilling at existing fields, which already possess 60 percent of USSR production wells, [104] but the returns will prove small. Production in Krasnodar' and Stavropol' Krays will continue to

[39] Because Urals-Volga and Azerbaijan gasfields—the other "older fields"—have been of minor importance to gas production, the appendix discussion will deal only with fields in the Ukraine and the North Caucasus.

Figure A-1

USSR:
Production of Older
Gas-Producing Regions



nosedive because additional reserves are not there.[105] More than 30 percent of Krasnodar' wells and 13 percent of Stavropol' wells were inactive in 1975.[106] Outlays for capital and labor have continued at high rates, however, while returns have plummeted. Stavropol' extraction costs in 1971-75 rose 250 percent; those for Krasnodar', 600 percent (see tables A-1 and J-17).[107] Ukrainian extraction, still one of the most important factors in Soviet gas supply, will begin to diminish substantially in 1978-80.

If Soviet plans for 1980 in the Ukraine are to be met—which is unlikely—major investment will be required. In fact, up to 350 new production wells are planned for the 1976-80 period.[108] With extraction in the Shebelinka field falling rapidly (see figure A-2), however, the newer but smaller fields will not nearly cover the republic's output losses. The Krestishchensk field is now the leading Ukrainian field, but its output probably will peak by 1980. Return on investment, already declining (see table A-2), will continue, and 1980 production in the Ukraine could fall below 50 billion cu m.[40] Offshore production in the Black and Azov Seas will aid Ukrainian output in the mid-1980s, but will not stop an accelerated production decline.

Dwindling output from the older producing regions in the next decade will clearly act as an increasing drag on the gas industry's performance. The Ukraine's role in supplying gas for export will seriously diminish. It is probable that the USSR will fail to reach the 1980 plan's upper range of 435 billion cu m. Such failure will be due in no small part to the lack of production capacity in the old fields, which will continue to tie up much of the industry's annual investment and fixed capital at least through 1980, while their share in national extraction will drop to roughly 18 percentage points. Yet because the old fields are now producing more than one-fourth of total gas output, Moscow may not feel that it can afford to reduce investment in them sharply.

[40] A 1976-80 aggregate production goal for the Ukraine of 265 billion cu m *(Neftyanaya i gazovaya promyshlennost'* no. 1 (January-March 1977, p. 2) suggests an annual average output of 53 billion cu m for the period. Since Ukrainian production in 1976, 1977, and perhaps 1978 and 1979 is scheduled to be higher than that, 1980 output apparently is planned to be considerably lower than 53 billion.

Figure A-2

SHEBELINKA FIELD, UKRAINE:
Natural Gas Production

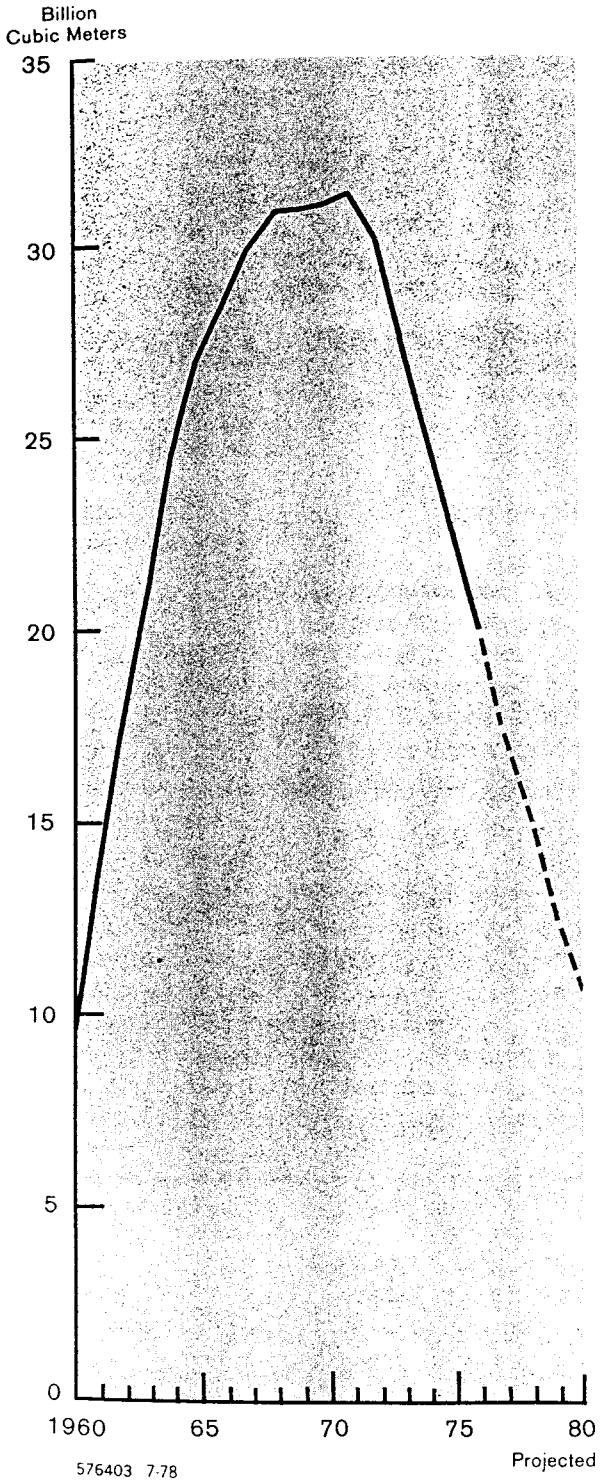


Table A-1

Gas Production in Krasnodar' Kray

	Production [1] (Billion Cubic Meters)	Total Wells [2]	Producing Wells [2]	Output per Well (Million Cubic Meters/Year)	Output/Capital Ratio (Cubic Meters/Ruble)	Production Cost (Rubles/Thousand Cubic Meters)
1961	5.7	88	62	92	310	0.45
1964	16.4	206	178	92	370	0.38
1966	23.3	319	282	83	335	0.46
1968	24.5	367	357	69	265	0.54
1970	21.3	394	384	55	195	0.77
1972	13.3	389	365	36	110	1.35
1975	5.8	818	587	10	NA	5.47

[1] Does not equal total production for kray because the data represent output from 10 major fields only. Sources: Brentz, *Ekonomika gazodobyvayushchey promyshlennosti*, pp. 49-51; Margulov, *Razvitiye gazovoy promyshlennosti*, p. 29; S. A. Orduzhev, *Gazovaya promyshlennosti po puti progressa*, Moscow (1976), p. 30.

[2] Estimate.

Table A-2

Selected Ukrainian Gas Field Production [1]

	Production (Billion Cubic Meters)	Production Wells		Output per Well (Million Cubic Meters/Year)	Output/Capital Ratio (Cubic Meters/Ruble)	Production Costs (Rubles/Thousand Cubic Meters)
		Total	Active			
Eastern Ukraine						
Shebelinka						
1957	1.9	24	23	129	160	0.33
1960	8.9	80	70	159	417	0.28
1965	26.9	238	227	133	455	0.26
1970	31.0	393	388	82	294	0.36
1971	31.3	423	419	77	260	0.40
1972	30.1	454	423	72	225	0.48
1973	27.5	482	474	62	183	0.54
1974	25.0	511	502	51	157	0.64
1975	22.7	535	531	44	128	0.99
1976	19.8	556	543	37	108	1.18
Krestishchensk						
1970	0.3	3	3	100	52	1.48
1971	2.6	12	8	175	170	1.37
1972	6.1	20	18	475	250	0.29
1973	9.5	30	26	430	236	0.28
1974	14.1	48	41	345	292	0.40
1975	18.6	63	61	305	260	0.42
1976	21.4	84	83	300	233	0.56
Western Ukraine [2]						
1961	5.0	90	75	67	400	0.26
1965	7.1	94	88	81	380	0.25
1970	6.0	147	144	42	235	0.35
1972	4.4	133	125	34	175	0.45

[1] Sources: Brentz, *Ekonomika gazodobyvayushchey promyshlennosti* (1975), pp. 61-64; *Geologiya, bureniye i razrabotka gazovykh mestorozhdeniy*, no. 17 (1977), no. 17 (1977), p. 15.

[2] Data from four fields: Ugersko, Bilche-Volitza, Rudki, and Khodnovichi. Data for years other than those shown were not available.

APPENDIX B

CENTRAL ASIA

Soviet Central Asia [41] is playing a short-run but crucial role as the USSR's leading gas producer. In that capacity the region has:

(1) Increased its gas output from 40 billion cu m in 1969 to 105 billion cu m in 1976, thereby contributing almost 50 percent of the annual increase in total Soviet production during that period.

(2) Supplied nearly one-third of the national output in 1975-77.

(3) Surpassed Ukrainian production beginning in 1973. In effect, Central Asia during the late 1960s and early 1970s served as a swing producer—making up for declining output in the European USSR while West Siberia's reserves were being developed—and became an important gas supplier for both Soviet and European consumers.

Central Asia's emergence as a gas producer was dramatic, although it will soon be overshadowed by West Siberia's performance. Central Asia's output in 1976 was nearly 134 times that of 1960. During 1961-76, output grew at an average annual rate of 36 percent. Most impressive was the region's ability to maintain a 14-percent annual growth rate during 1971-75, nearly doubling the already substantial production level of 1970. Thus, within 15 years Central Asia's contribution to Soviet gas supplies rose from 2 percent to almost one-third.

The region's output maintained this pace by developing in two stages. Following the opening of the large Gazli field in 1961, Uzbek was responsible for the rapid rise in Central Asian gas output (see table B-1), providing 78 percent of the region's production increase during 1961-69. As Uzbek's growth slowed in the 1970s, Turkmen's output skyrocketed.[109] Production rose at an annual rate of 35 percent during 1970-76, jumping from 7.5 billion cu m to 63 billion cu m. Turkmen's output accordingly climbed to 60 percent of Central Asian production and provided about 85 percent of regional growth in that period.

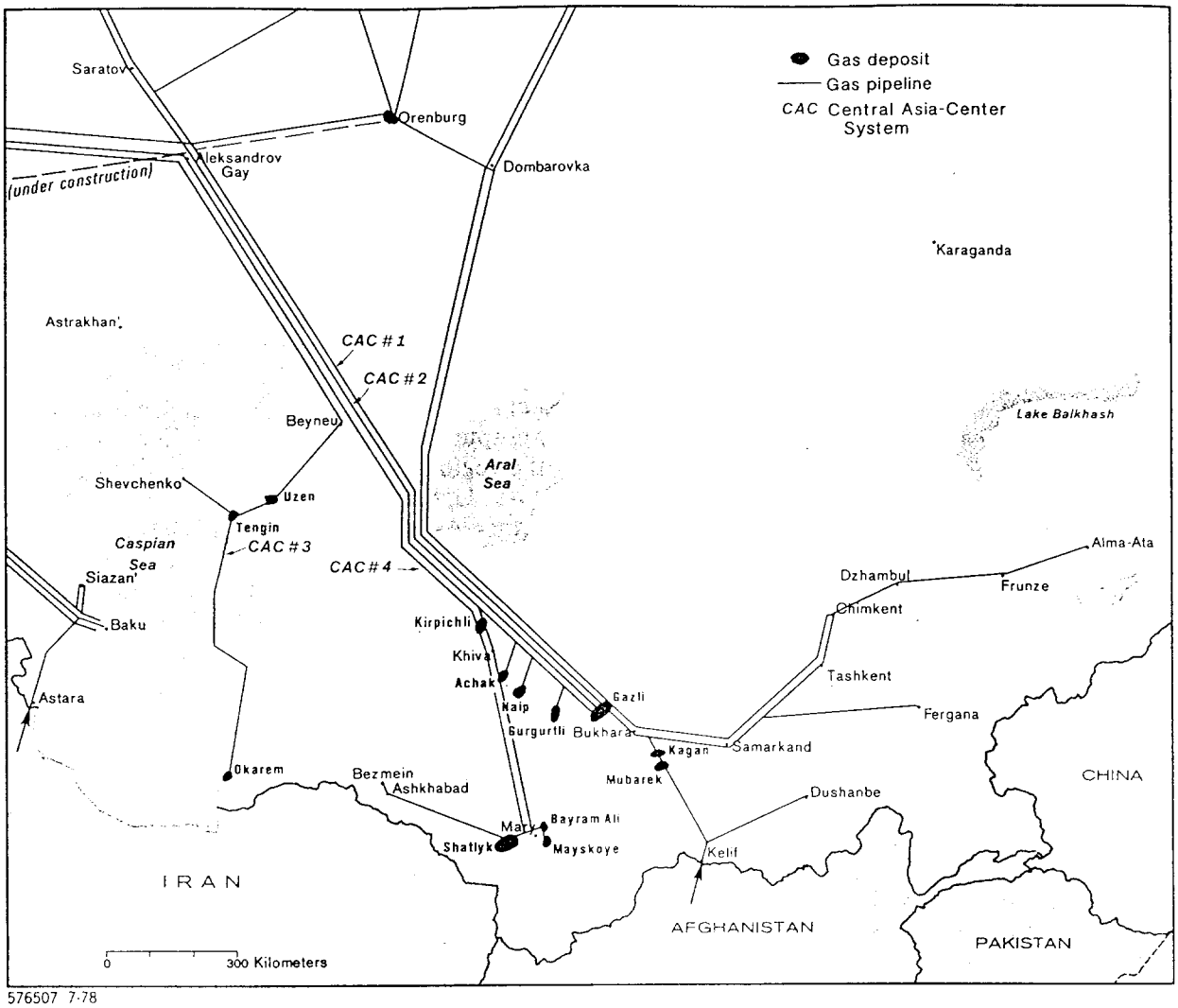
Central Asia's gas consumption is relatively low, and the bulk of its production, from roughly 600 wells, [42] is piped elsewhere. [110] Uzbek has supplied the Urals and the Moscow region since the mid-1960s via several large trunklines (see appendix I and the map). Turkmen's production boom has been handled by completion—although tardily—of the Central Asia–Center pipeline system, which can transport yearly up to 90 billion cu m of Uzbek-Turkmen gas. Although much of the Turkmen gas is going to European USSR consumers, much is also going to European importers via linkups with trunklines in the Ukraine. Barring extremely sharp drops in Ukrainian extraction, Central Asia should provide enough gas to maintain Soviet export capacity until Orenburg and West Siberia's fields can take over.

Nonetheless, Central Asia's role as the leading gas supplier will end soon. Not only will West Siberian production exceed the desert region's output, Central Asia's growth will slow considerably. The region's reserves—roughly 3 billion cu m [111]—are much smaller than those of northern Tyumen' Oblast, and Uzbek's output is

[41] As defined here, the southernmost region of the USSR east of the Urals composed of the Socialist Republics of Turkmen, Uzbek, Kirgiz, Tadzhik, and Kazakhstan.

[42] Uzbek and Turkmen only.

Soviet Central Asian Gas Fields and Gas Pipelines



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declining, leaving Turkmen alone to provide further increases. Turkmen's current high growth rate will also slow during 1978-80.

Production from the Uzbek SSR peaked in 1973 and has declined slowly since then. Extraction in 1976 was 3 percent below 1973 and probably will fall at a similar or higher rate through 1980. New additions to reserves are small (see table 12), and Uzbek's principal fields have all passed their prime. The largest field, Gazli, still accounts for most of Uzbek's gas extraction. Its production rose meteorically in the mid-1960s, providing one-seventh of Soviet output in 1966-68, and peaked in 1971 at 26.4 billion cu m (see table B-2). Production by 1976 was approximately 20 billion cu m—a drop of about 25 percent. Gazli's production costs in 1976 were still fairly low compared with those of fields in Turkmen and Tyumen', but its costs will rise markedly as output continues to fall. Uzbek's supply to major Soviet consuming centers will also shrink substantially as the republic increasingly diverts its output to Central Asia's own growing gas consumption.

Future growth of Central Asian gas production will come from Turkmen, although all the major fields that boosted the republic's output in the early 1970s are at or near their peaks. The Achak field is fully developed and Naip has almost reached full production. Most important, the massive Shatlyk field's output, planned to reach 35 billion cu m in 1977, [112] has apparently peaked. No similar field is in sight. Most Turkmen deposits—known and potential—are

below 3,000 meters and will probably prove much smaller than Shatlyk's. Thus, even if Shatlyk sustains its peak output for a decade—which is unlikely—Turkmen's ratio of reserves to production will fall, hampering production growth in the 1980s. The Turkmen gas production association was scheduled to produce only 57 billion cu m in 1977, [113] against 55 billion cu m in 1976. Declining extraction rates at sections of the Achak and North Achak fields in fact have already occurred. [114] Smaller fields like Okarem, Tedzhen, Bayram Ali, Kirpichli, and Sakar could add more than 20 billion cu m to Turkmen output by the early 1980s. [115] They may not reach peak capacity soon enough, however, to enable the republic to meet its plan of 75 billion to 80 billion cu m for 1980. These and other small fields will expand production only slightly before it peaks in the early 1980s, and Central Asia will fall behind West Siberia as the nation's leading source of natural gas.

Table B-1

Central Asian Production of Natural Gas [1]

	Production (Million Cubic Meters)	Percent of USSR Output	Uzbek Output as Percent of Central Asia	Turkmen Output as Percent of Central Asia
1960	781	1.7	57.2	30.0
1961	1,451	2.5	69.9	16.7
1962	2,488	3.4	81.7	10.2
1963	3,410	3.8	87.7	7.5
1964	10,197	9.4	91.4	6.8
1965	17,867	14.0	92.2	6.5
1966	24,130	16.9	93.5	5.2
1967	29,448	18.7	90.5	7.6
1968	34,809	20.6	83.3	13.9
1969	39,763	22.0	77.4	18.9
1970	48,048	24.3	66.8	27.3
1971	54,129	25.4	62.2	31.2
1972	59,469	26.9	56.7	35.8
1973	71,512	30.3	51.9	40.1
1974	82,527	31.7	44.9	47.6
1975	94,011	32.5	38.8	55.1
1976	104,530	32.6	34.4	59.9

[1] Source: *Narodnoye khozyaystvo SSSR*, various issues.

Table B-2

Uzbek SSR: Economic Data From Gazli Gasfield [1]

	Production (Billion Cubic Meters)	Output per Well (Million Cubic Meters/Year)	Output/Capital Ratio (Cubic Meters/Ruble)	Cost of Extraction (Ruble/Thousand Cubic Meters)
1962	0.7	175	455	0.67
1963	1.8	95	192	0.59
1964	8.4	180	505	0.28
1965	15.4	220	635	0.16
1966	21.4	205	700	0.15
1967	23.9	150	655	0.15
1968	24.9	140	640	0.15
1969	25.3	140	650	0.15
1970	26.1	140	670	0.16
1971	26.4	135	675	0.16
1972	23.0	115	575	0.16

[1] Source: Brentz, *Ekonomika gazodobyvayushchey promyshlennosti*, p. 66.

APPENDIX C

WEST SIBERIA

West Siberia is the Soviet gas industry's great frontier in terms of the region's distance from major consuming centers, its production potential, and its expected costs. East Siberia and the Soviet Far East may eventually attain similar status, but only West Siberia has proved-plus-probable reserves massive enough to make it the focal point of the gas industry's planning through the 1980s. Moscow expects the region during 1976-80 to:

(a) Increase its share of gas reserves (A + B + C_1) to more than 70 percent of the national total.

(b) Account for more than 80 percent of all increases in Soviet gas output.

(c) Become one of the principal suppliers for European gas consumers.

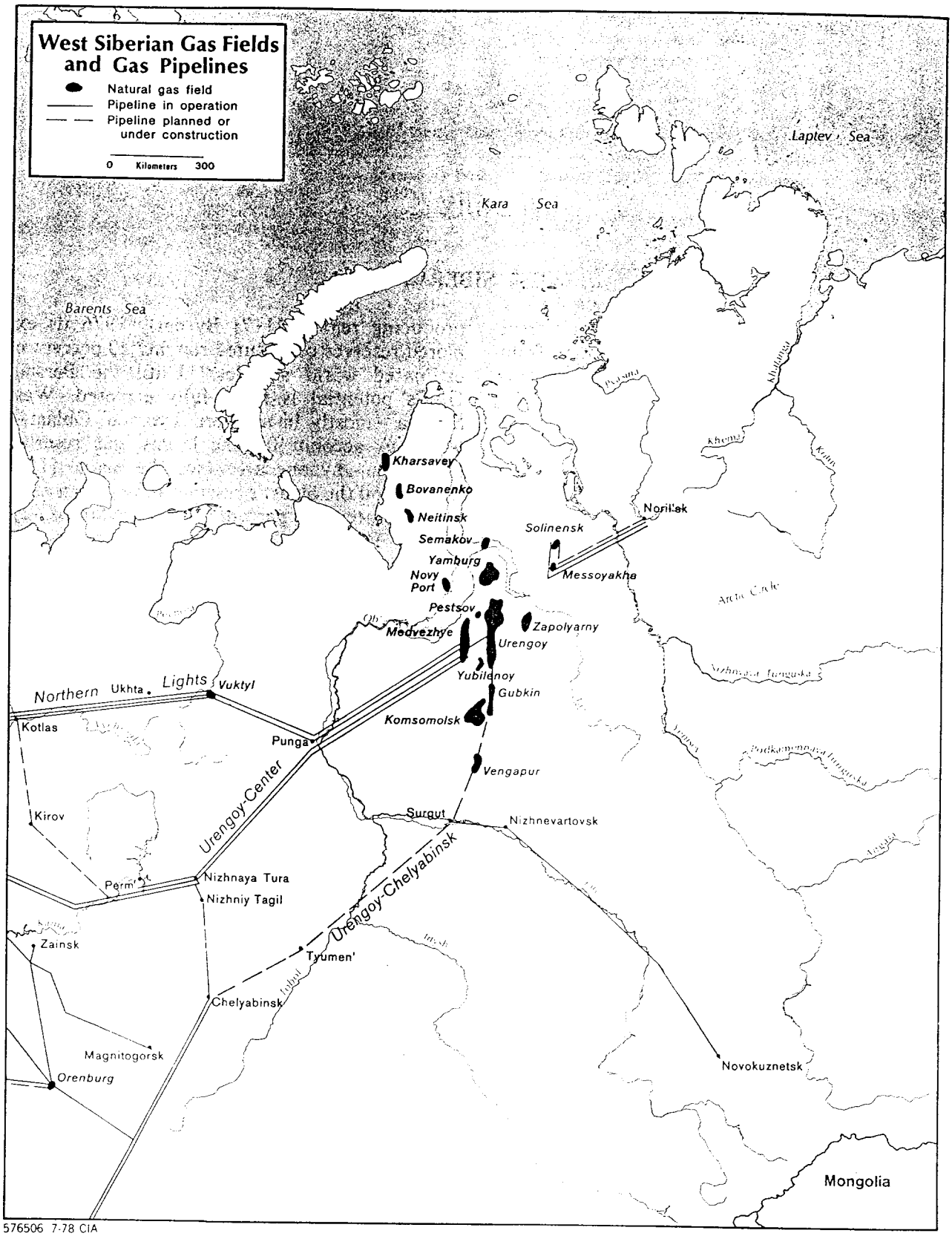
West Siberia's promise for the gas industry, however, is matched by the problems it presents. The Soviets have been allocating increasingly large sums to projects related to the region's development (see table C-1). During 1976-80, Moscow may devote almost 80 percent of the 19 billion rubles in gas industry investment to West Siberian–related projects. [116] However, the region's gas production in the next few years probably will not match publicized Soviet expectations. Well into the next decade, West Siberian gas output will suffer from a serious lack of infrastructure, slow development of giant fields, continuing problems with pipeline construction, and unprecedented costs.

Production Potential

West Siberia shares with the Persian Gulf the potential to become the world's leading gas-producing region. [117] By early 1976 its explored reserves constituted roughly 20 percent of estimated world supplies.[43] Until the Persian Gulf's potential is more fully explored, West Siberia—mostly in northern Tyumen' Oblast—will thus account for the largest gas reserves located in any one area (see the map). [118] Since 1960 the oblast's reserves have grown at an average rate of 44 percent a year (see table C-2), and by 1977 they accounted for 61 percent of total Soviet reserves. More than 80 percent of the reserves in Tyumen', moreover, are in a handful of large fields (see table C-3). [119] Indeed the Urengoy field, with reserves of more than 5 trillion cu m, may be the world's largest. [120]

Exploratory drilling in northern Tyumen' has been very effective. Total exploratory drilling for gas in the region has not been as extensive as in Turkmen, Orenburg, and some older producing regions; nor has it equaled exploratory drilling for oil in southern Tyumen' (0.6 meters drilled per square kilometer for northern Tyumen' to 10.4 meters per square kilometer in southern Tyumen'). [121] Additions to reserves per meter drilled in northern Tyumen', however, were 20 million cu m in 1966-70 and 72 million cu m in 1971-75—both unprecedented results. [122] Similarly, with Tyumen' gas production still relatively low, the oblast's ratio of reserves to production is far higher than the Soviet average. These indicators will drop as new reserves become harder to find and as production rises. Nonetheless, the Soviets expect Tyumen' reserves to increase by several trillion cu m by 1980—an attainable goal that will provide most of the increase in total USSR reserve capacity during the balance of the 1970s. [123]

[43] A + B + C_1 categories.


West Siberian Gas Fields and Gas Pipelines
Natural gas field
Pipeline in operation
Pipeline planned or under construction
0 Kilometers 300
Laptev Sea
Kara Sea
Barents Sea
Kharsavey
Bovanenko
Neitinsk
Semakov
Yamburg
Novy Port
Pestsov
Medvezhye
Urengoy
Zapolyarny
Yubileynoy
Gubkin
Komsomolsk
Vengapur
Surgut
Nizhnevartovsk
Solinensk
Norilsk
Messoyakha
Arctic Circle
Northern Lights
Ukhta
Vuktyl
Kotlas
Punga
Urengoy-Center
Kirov
Perm'
Nizhnaya Tura
Nizhniy Tagil
Urengoy-Chelyabinsk
Zainsk
Tyumen'
Chelyabinsk
Magnitogorsk
Orenburg
Novokuznetsk
Mongolia
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Soviet planners expect gas production in northern Tyumen' Oblast to skyrocket. Since the Medvezh'ye gasfield began production in 1972, the region's output has climbed substantially. Gas extraction reached 68 billion cu m in 1977—20 percent of the Soviet total. [124] With the Urengoy field having come onstream in 1978, the Soviets expect the gasfields of northern Tyumen' Oblast to produce 139 billion cu m in 1980. [125] The remainder of the 155-billion-cu m plan target for Tyumen' as a whole will be filled by increased production of associated gas at the oblast's oilfields—notably Samotlor. The planned increase in Tyumen' gas production would provide more than 80 percent of the increase in national output and would raise the share of Tyumen' in that output to 35 percent. However, regional production of only 120 billion cu m to 130 billion cu m seems a more likely prospect. Medvezh'ye provided most of the growth until it peaked at approximately 65 billion cu m in 1977. [126] Urengoy subsequently will account for most of the increases in Soviet output until the mid-1980s. By then other large Tyumen' fields may have been developed, making the region responsible for well over half of Soviet gas production.

Pipeline construction will play a crucial role in the Tyumen' gas industry's success or failure in meeting the 1980 plan. To satisfy Moscow's commitments to domestic consumption and foreign trade, the Soviets are installing some of the world's largest gas trunkline systems. Three major systems—Northern Lights, Urengoy-Center, and Urengoy-Chelyabinsk (see appendix I)—lead from the Urengoy, Vyngapur, and Medvezh'ye fields and are planned to exceed 150 billion cu m in combined capacity by 1980. The Northern Lights and Urengoy-Center systems are partly complete and are supplying gas to the European USSR. By the early 1980s, the expanded network could also handle much of Soviet exports to Eastern and Western Europe.

Problems of Development

Realizing the gas potential of northern Tyumen' will prove time-consuming and costly.[127] The 1980 production goal probably will not be met, even though total allocations to the Tyumen' gas industry will almost certainly exceed the approximately 15 billion rubles apparently planned for 1976-80. The Soviets clearly expect delivered costs of Tyumen' gas to soar above those for other new fields, as development time increases and investment follows suit, as indicated by data in table C-4. The 1975 ratio of output to capital for the Nadym Gas Production Association (operating the Medvezh'ye field) was below the USSR average (see table J-16). The cost of drilling a gas well in Tyumen' ranges from four to six times higher than in the European USSR.[128]

Leading causes of slow and expensive development of West Siberia's gas industry are discussed in the following two sections.

Lack of Infrastructure. An efficient network of roads and railways in northern Tyumen' has yet to be built. The Surgut-Urengoy, Nadym-Urengoy, and Yamal railways are lagging in construction and need to be supplemented by all-weather roads. Installation of such roads would require 1.2 million to 1.6 million rubles per kilometer,[129] compared with 0.12 million rubles in the European USSR.[130] Production support facilities—such as intrafield roads, supply depots, repair facilities, and power supply—remain inadequate. Entire towns—notably Nadym and Urengoy—are being erected for the labor force which, because of the rugged living conditions, is paid wages more than twice those for workers at older fields.[131]

Infrastructure development consequently consumes a large portion of investment, as indicated by the Medvezh'ye field's experience (see tables C-5 and C-6).[132] Not only have infrastructure expenditures constituted a relatively large portion of Medvezh'ye's capital allocations (they will easily exceed 1 billion rubles by 1980),[133] but they have also been principally responsible for raising the cost [44] of Medvezh'ye's stock of fixed reproducible assets to eight times that for the next largest Soviet field currently in production.[134] The number of nonproduction support personnel required to maintain infrastructural

[44] Does not include a capital charge.

and social services has been larger and faster growing than the ranks of production workers themselves.[135]

Until huge sums are spent on improving the Tyumen' road, river, and rail systems, airfield facilities, and local production base, large expenditures will go toward a makeshift form of supply.[136] Most materials and equipment are now brought part way by ship and rail. In winter, supplies can be further transported overland by truck or tractor. During much of the year, however, the tundra, permafrost, and swamp conditions make ground transport difficult, and air shipments are essential. The high cost of either mode of transport is compounded by the inability of Tyumen' to supply more than a small portion of its own construction materials.[45] Heavy cargoes, therefore, must be moved over long distances, often with many reloadings and delays that, according to Soviet statements, render useless 20 percent of delivered materials through accidents, rust, and other problems of long exposure to weather. [137] Poor coordination among the 20 agencies involved in West Siberian oil and gas production is a major factor in this regard. As a result, aggregate freight costs are enormous. An article in one Soviet journal indicates that the recent average of 80 rubles per ton is expected to rise at least five times by 1980. [138] Air transport alone has already accounted for 30 percent of Medvezh'ye's costs. [139]

Technology. West Siberia's inhospitable climate and terrain continue to test the gas industry's technical capabilities. Pipeline construction and maintenance in permafrost and swamp is the greatest problem. [140] Pipeline stress and corrosion would be alleviated by improved pipe metals and by gas cooling facilities, but these probably will not be widely available in the region for several years. High-capacity, automated collection stations will also prove slow in arriving, causing field development bottlenecks. Drilling of large-diameter wells will permit unprecedented flow rates (up to 1 million cu m per day) [141] but may also increase problems of well completion. Melting of permafrost around wells producing high-pressure gas can cause severe wellhead subsidence and casing collapse, halting production. Natural thawing and refreezing of permafrost produces similar results. Improved casing materials and well refrigeration are needed, [142] but will not be introduced quickly. Improved ground transportation—such as air-cushion vehicles for movement of men and equipment over marshy tundra [143]—is another urgent need that will not be widely filled until after 1980, when large-scale manufacture of vehicles currently being tested may become possible.

Toward 1980 and Beyond

Inadequate pipeline capacity will be the most likely constraint on northern Tyumen' gas output during 1978-80. The Soviets apparently are intensifying development of the Urengoy field to enable it to produce an estimated 58 billion to 60 billion cu m by 1980. [144] If the required gas collection lines and processing equipment are installed within the next three years, Urengoy should reach or come close to that target. Development has also begun at the neighboring small field of Vyngapur (scheduled to produce 5 billion cu m in 1978 and perhaps up to 18 billion cu m in 1980 [145]), whose output by 1980 can probably fill the rest of the 139–billion–cu m goal not covered by Urengoy, Medvezh'ye (65 billion cu m), and older northern Tyumen' fields. The relatively small fields of Gubkin, Yubilenoy, and Komsomol'sk may also be undergoing initial development.

However, the capacity of the region's pipeline system—estimated at 70 billion cu m in early 1978—probably will not expand quickly enough to reach the 139 billion cu m required by early 1980. The additions of new lines—several of them 1,400-mm pipe—to the Northern Lights and Urengoy-Center systems and laying of at least the first line of the Urengoy-Chelyabinsk system may be completed by the late 1970s. Installation of compressor capacity, on the other hand, probably will lag considerably. More than 60 compressor stations—each with several com-

[45] Northern Tyumen' plants supply only 50 percent of reinforced concrete, 15 percent of crushed rock, 25 percent of gravel, and 20 percent of woodworking products needed for gas industry installations. *Gazovaya promyshlennost'*, no. *3 (1976)*, p. *14*.

pressor units—will be required on the three systems, [146] with many units coming from Western companies. The long leadtimes required for Western manufacture and for shipment to the compressor station sites are likely to delay the installation of many units until 1980 or 1981. The Soviets may raise the capacity of the first Urengoy-Vyngapur-Chelyabinsk line to its projected 33 billion cu m/year by 1980 through a crash program, although this is not likely. [147] Capacity on the other two systems is unlikely to carry the remainder of the 139 billion cu m. In fact, the three systems may move only 115 billion to 120 billion cu m, causing most of the predicted Soviet gas production short-fall in 1980.

Beyond 1980, the Tyumen' gas industry's development will start to concentrate on deposits further north. Urengoy and the smaller fields now undergoing initial development will receive additional drilling during 1981-85. Zapolyarny and Yamburg, however, are the most likely targets for new, intensive development in that period.[148]

Because permafrost conditions are worse at those fields than at Medvezh'ye and Urengoy and because lack of infrastructure will again constitute a serious problem, investment in Tyumen' gas in 1981-85 will increase sharply over that for 1976-80. At least 2 billion rubles will go into infrastructure alone. Yet heavier investment probably will bring neither Yamburg nor Zapolyarny production near full capacity. Soviet technology may prove unable to deal rapidly with harsher permafrost conditions, in both field development and pipeline construction. The latter may again become the leading bottleneck, since existing Tyumen' pipeline systems will require substantial expansion to handle Yamburg and Zapolyarny gas. Improvement of Soviet ability to manufacture and install large-diameter pipe and compressors is possible beyond 1980, but such progress probably will be slow. Infrastructure, drilling, and pipelaying problems could prove even worse at the Kharsavey and Bovanenko fields on the forbidding Yamal Peninsula, where development is unlikely to produce significant additions to the Soviet gas supply until the late 1980s.

Table C-1

Annual Capital Investment in Northern Region Gas Projects as Percent of Total Gas Industry Investment [1]

1970	1971	1972	1973	1974	1975
6.6	14.8	25.1	31.8	33.8	39.2

[1] Not all projects accounted for here strictly involved Tyumen' Oblast gas. However, most investment, particularly in the later years shown, was most likely tied to that region's gas industry. Source: *Ekonomika gazovoy promyshlennosti*, no. 8 (1977), p. 36.

Table C-2

Tyumen' Oblast Gas Industry [1]

	Reserves ($A+B+C_1$) Billion Cubic Meters	Percent of USSR Reserves	Production (Billion Cubic Meters)	Percent of USSR Output	Reserves/ Production Ratio
1960	50.2	2.2	0	0	
1961	50.2	2.0	0	0	
1962	70.1	2.5	0	0	
1963	130.1	4.2	0	0	
1964	200.3	6.2	0	0	
1965	300.3	8.4	0	0	
1966	400.8	11.2	0.6	0.4	668
1967	895.8	20.4	5.2	3.3	172
1968	4,030.6	42.8	8.2	4.8	492
1969	4,914.3	40.7	9.1	5.0	540
1970	6,834.9	56.5	9.2	4.6	743
1971	9,252.3	58.7	9.3	4.4	995
1972	10,608.7	58.9	11.4	5.1	931
1973	11,797.4	60.4	15.8	6.7	747
1974	13,749.5	61.3	21.8	8.4	631
1975	15,490.0	63.0	36.8	12.7	421
1976	17,000.0	61.0	44.0	13.7	386
1977	NA	NA	67.9	19.6	NA

[1] Sources: Brentz, *Ekonomika gazodobyvayushchey promyshlennosti*, p. 28; *Geologiya, bureniye i razrabotka gazovykh mestorozhdenii*, no. 4 (1977), p. 3; *Ekonomicheskaya gazeta*, no. 24 (1978), p. 1.

Table C-3

Major Gasfields of Tyumen' Oblast [1]

	Surface Thickness [2] (Meters)	Year Discovered	Reserves [3] (Billion Cubic Meters)	Depth of Producing Zones (Meters)	Temperature (Degrees Centigrade)	Pressure [4] (Kilograms per Square Meter)	Porosity [5] (Percent)	Permeability [6] (Millidarcies)	Methane Content (Percent)	Well Yields (Thousand Cubic Meters per Day)	Known Production Wells Drilled	Output in 1977 (Billion Cubic Meters)
Urengoy	350-500	1966	5,000	1,100-3,100	32-88	119	25-30	950-1,750	84-98	1,000	45	0
Yamburg	350-400	1969	3,000	1,000-1,200	70-78	114	Up to 37	Up to 3,632	NA	200-700	NA	0
Zapolyarnyy	400-450	1965	2,000	1,100-1,300	27	128	24-37	10-7,654	98	150-250	NA	0
Medvezh'ye	350-600	1967	1,548	1,060-1,210	28-35	114	24-35	400-800	99	1,000	100	65
Kharsavei	Thickness unknown	1974	1,000	1,500-1,600	48-52	155-163	NA	NA	NA	Up to 1,000	NA	0
Bovanenko	Thickness unknown	1971	1,000	570-1,500	NA	NA	NA	NA	NA	300-450	NA	0
Semakov	Thickness unknown	1971	541	NA	20	89	NA	NA	NA	NA	NA	0
Neitinsk	Thickness unknown	1974	498	NA	NA	NA	NA	NA	NA	NA	NA	0
Komsomol'sk	200-250	1966	457	850-1,000	30	99	25-30	Up to 6,000	97	43-1,195	NA	0
Gubkin	120-200	1965	353	665-780	21	77	25-35	Up to 7,000	96	270-867	NA	0
Pestsov	Thickness unknown	1974	300	NA	NA	NA	NA	NA	NA	NA	NA	0
Vyngapur	200-250	1968	292	920-1,040	30	103	NA	NA	NA	450-686	NA	0
Yubilenoye	350-425	1969	221	1,025-1,180	32	112	NA	NA	NA	Up to 5,200	NA	0
Solinensk	360-450	1970	161	2,250-2,450	50	240	NA	NA	NA	300-500	NA	NA
Novyy Port	350-450	1965	100	900-2,100	24-49	87-182	10-20	65-150	79-92	45-1,100	NA	0
Messoyakha	360-450	1967	44	790-900	13	78	20-32	1-500	92-98	150	55	3.0

[1] Fields included were selected because they possess large reserves and/or because significant data were available.
[2] Thickness of tundra and permafrost in meters.
[3] A + B + C_1. Most reserve figures for West Siberian fields include B + C_1 only.
[4] Pressure exerted on the gas within the reservoir.
[5] The proportion of a reservoir rock's total volume which is occupied by the space between the mineral grains.
[6] The degree to which a rock will permit the gas to pass through it.

Table C-4

Comparison of Delivered Costs

Producing Area	Pipeline Used	Rubles per Thousand Cubic Meters [1]
Tyumen' Oblast	Nadym-Moscow	16-18
Shatlyk Field	Central Asia-Center	12-13
Komi ASSR	Ukhta-Center	8

[1] Soviet calculations. Does not include capital charge. Source: *Ekonomika gazovoy promyshlennosti*, no. 2 (1975), p. 12.

Table C-5

Allocation of Capital Investment at Selected Gasfields[1]

Percent

Area of Investment	Gazli (Uzbek SSR)	North Stavropol'	Medvezh'ye (Tyumen' Oblast)
Total	100.0	100.0	100.0
Wells	48.5	38.4	15
Collection lines	26.5	43.6	18
Collection stations	9.5	2.4	14
Roads	4.9	5.4	14
Other	10.6	10.2	9
General regional improvement [2]	0	0	30

[1] Source: *Ekonomika gazovoy promyshlennosti*, no. 2 (1975), p. 13.
[2] Including housing and other living facilities.

Table C-6

Selected Gasfield Data [1]

Field	Production (Billion Cubic Meters)	Initial Reserves (Billion Cubic Meters)	Average Output per Well (Thousand Cubic Meters/Day)	Depth of Producing Zones (Meters)	Fixed Capital/ Production Ratio (Rubles/Thousand Cubic Meters)	Production Cost[2] (Rubles/Thousand Cubic Meters)
Shebelinka	30	550	500	2,000	2.8	0.31
Gazli	26	460	700	850-1,150	1.9	0.28
North Stavropol'	15	229	360	825	2.4	0.32
Medvezh'ye	65	1,548	1,500	1,200	22.8	1.60

[1] Data for the first three fields represent the period when each was at peak production. Medvezh'ye data are Soviet projections for peak performance expected to begin in 1978. Source: *Ekonomika gazovoy promyshlennosti*, no. 2 (1975), p. 13.
[2] Sebestoimost', without a capital charge.

APPENDIX D

GAS PROCESSING AND REFINING

Treatment of extracted gas before its transport by pipeline is becoming increasingly important to the Soviet gas industry. Several problems are developing in routine gas processing—the collection and preparation of natural gas for transport—in Central Asia and West Siberia. At a growing number of fields in those two leading gas-producing regions, improved equipment is required (a) to collect gas under extremely high temperatures and, in the case of Central Asia, high pressure and (b) to remove impurities such as hydrates and carbon dioxide. Significantly expanded automation of that equipment is also needed in desert and permafrost areas where there is a shortage of skilled labor.

Of particular importance to the gas industry, however, are processing of associated gas and natural gas refining. Moscow wants to reduce the waste of associated gas by enlarging the oil industry's capacity to separate the gas extracted with oil and to prepare it for pipeline transport. It also wants to increase through expanded refining capacity the natural gas byproducts—such as propane, butane, sulfur, carbon black, and stable condensate—available for use in chemical production and in other industries.

Associated Gas

One of the weakest facets of Soviet gas production is recovery of associated gas, which has grown only slowly (see table J-2). As extraction of associated gas increased along with the rapid expansion of oil production the share of the total processed fell from 70 percent in 1965 to 59 percent in 1975, when 20 billion cu m was flared (table D-1). In contrast, about 87 percent of all gas extracted outside the USSR in 1974 was processed or reinjected. Although processed associated gas contributed only 10 percent of national gas output, an accelerated expansion of processing capacity over the past decade could have brought the Soviets much closer to fulfilling production plans.

Moscow has attached considerable importance to expanding the use of associated gas during the current five-year plan. Processing is expected to increase by more than 40 percent to reach 40 billion to 45 billion cu m by 1980.[149] Key sites for additional plants are the Tyumen' oil region and the Kazakh and Turkmen oilfields along the east Caspian coast. Processing capacity is already considerable in older oil-producing regions such as the Tatar ASSR, the Ukraine, the Caucasus, and the Kuybyshev district (see table D-2).

The Soviets will not easily reach the 1980 goal for processing associated gas. Moreover, even if they could, it would not end flaring of substantial amounts of gas. The Ministry of the Petroleum Industry, which is responsible for almost all production of associated gas, has consistently moved slowly in constructing associated gas processing facilities. With minimal cooperation between the oil and gas ministries, investment in plants has been undercut by lags in equipment supply, in construction, and in use of the latest technology. An average of seven to eight years passes between an oilfield's first output and the installation of an associated gas processing unit.[150] This slow pace is likely to continue despite apparent Soviet interest in accelerating installation. A call for rapid growth of processing capacity in the 1971-75 plan [151] was followed by only 47-percent fulfillment. None of the three

West Siberian plants scheduled for that period were completed. The region's first such unit, a 4–billion–cu m–per–year facility at Nizhnevartovsk, was not finished until early 1976. [152]

Five plants are scheduled to be completed in West Siberia by 1980—two of them additional plants at Nizhnevartovsk to handle gas from the large Samotlor oilfield. [153] However, construction is falling behind schedule, possibly because of a lack of interministry coordination. Completing the West Siberian plants will be important, since roughly 10 percent of the region's plan target of 155 billion cu m for 1980 is to come from associated gas output. Even if West Siberia's 1980 goal for recovery of 16 billion cu m of associated gas [154] is reached, capacity will fall far short of that required to recover all of the associated gas being extracted in the area by that time. If the plan is seriously underfulfilled, West Siberia's recent annual flaring rate of 7 billion to 8 billion cu m [155] probably will not decline.

Natural Gas Refining

Natural gas refining by the Ministry of the Gas Industry has grown substantially since 1970 (see table D-3). By early 1976, refining was done by six Gas Ministry plants: facilities in Moscow, Ukhta, and Azerbaijan refine natural gas and condensate; a Shebelinka plant handles condensate; and a plant in Mubarek (Uzbek) and one at the Orenburg field both conduct sulfur removal. [156] Once the Orenburg plant reaches full capacity—in 1978-79 according to plans for the Orenburg–East Europe pipeline project (see appendix F)—refining should easily meet the 1980 plan of 31.5 billion cu m.

However, total refining capacity probably is not expanding as rapidly as it should to keep pace with needs. Large plants for handling condensate in northern Tyumen' Oblast probably will not be available until the early 1980s. Production associations in Central Asia, where the bulk of reserves may prove highly sulfurous, have not increased refinery capacity quickly enough, and one Turkmen newspaper has even recommended discovery of new, low-sulfur deposits rather than investing further in new refining facilities. [157]

Table D-1

Flaring of Associated Gas [1]

	Billion Cubic Meters
1965	7.1
1966	7.8
1967	9.0
1968	10.9
1969	12.4
1970	14.6
1971	15.9
1974	19.0
1975	20.0

[1] Sources: *Review of Sino-Soviet Oil* (September 1970), p. 7; (March 1972), p. 4; (May 1975), p. 22; *Ekonomika gazovoy promyshlennosti*, (February 1976), p. 7.

Table D-2

Output of Associated Gas by Oil Production Associations [1]

Million Cubic Meters

Association	1970	1971	1972	1973	1974	1975
USSR	22,958	24,967	25,746	26,482	27,620	28,573
Ministry of Petroleum Industry	22,911	24,915	25,685	26,430	27,590	28,566
Tyumen'	105	142	270	646	877	1,663
Tatar	3,882	4,125	4,236	4,243	4,323	4,398
Bashkir	1,364	1,333	1,371	1,408	1,446	1,469
Kuybyshev	2,167	2,131	2,119	2,024	1,974	2,022
Perm'	936	1,011	1,064	1,064	1,103	1,127
Mangyshlak	125	123	144	497	780	1,247
Turkmen	1,344	1,356	1,431	1,443	1,729	1,922
Ukraine	2,157	2,496	2,543	2,689	2,766	2,883
Grozny	4,252	4,768	4,509	4,084	3,954	3,058
Caspian	1,536	1,972	2,263	2,690	3,036	3,381
Orenburg	60	74	78	90	101	218
Komi	413	473	496	490	502	469
Belorussia	178	295	401	413	511	568
Stavropol'	692	760	805	827	835	836
Lower Volga	873	1,088	1,351	1,299	1,114	1,021
Azerbaijan	1,003	984	956	932	918	803
Krasnodar'	653	670	668	674	666	666
Udmurt	7	4	4	4	22	8
Sakhalin	388	308	216	201	227	198
Dagestan	490	484	451	382	386	275
Saratov	203	230	224	253	244	266
Uzbek	75	80	77	70	66	59
Kirgiz	6	4	4	2	0	0
Tadzhik	4	5	5	6	9	9
Ministry of the Gas Industry	47	52	62	52	31	7

[1] Source: *Ekonomika neftyanoy promyshlennosti*, no. 7 (1976), pp. 47-48.

Table D-3

Refining of Natural Gas [1] and Production of Products

	1970	1971	1972	1973	1974
Raw materials processed					
	Billion Cubic Meters				
Natural gas	3.1	3.3	8.4	10.1	21.5
	Thousand Metric Tons				
Condensate	2,236	3,259	4,410	4,951	5,442
Resulting products					
Liquid products [2]	449	627	858	997	1,052
Stable condensate	1,539	2,298	3,147	3,631	3,863
Carbon black	54.9	55.8	56.6	58.1	59.0
Sulfur	Negl	Negl	Negl	0.7	270

[1] Ministry of the Gas Industry. Source: *Ekonomika gazovoy promyshlennosti*, no. 8 (1975), pp. 26-27.
[2] Including propane and some butane.

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APPENDIX E

GAS STORAGE

Development of underground gas storage sites has increased substantially in the past decade, but gas in storage is still inadequate to prevent seasonal shortages in many consuming centers or to improve overall pipeline use. In the USSR, most stored gas is kept underground in depleted gasfields and in water-bearing strata—aquifers—located in the European USSR and in the Caucasus regions. The number of active storage sites increased from 10 to 25 during 1965-75 [158] (and to 26 by early 1977 [159]), with total storage capacity rising from 0.7 billion cu m in 1960 to 39.5 billion cu m in 1975. However, the volume of recoverable gas in storage increased only from 5 percent of consumption (2.5 billion cu m) in 1960 to 6 percent of consumption (18.3 billion cu m) in 1975 (see table J-22).

The sizable fluctuations in demand between summer and winter require a much larger reservoir capacity than exists now in the European USSR. Gas is usually in short supply in December-March and in surplus during May-August. During the winter of 1975-76, for example, 13 billion cu m were withdrawn from stocks to meet increased seasonal demand.[160] A larger storage capability would make possible storage of surplus gas in the summer and thus ensure greater wintertime reliability of gas supplies for household and industrial users. It would also permit pipelines to operate at optimal average pressures—requiring less compressor power—rather than being geared to peak demand.

Industry planners are calling for an increase in the volume of stored recoverable gas to 45 billion cu m (10-12 percent of demand) by 1980.[161] However, finding additional aquifers, exhausted gas deposits, or salt cavities near major trunklines or distribution networks is difficult. A large percentage—in some cases about one-half—of the gas pumped into underground reservoirs may be lost because of the Soviet use of flat (rather than domed) structures which lack structural closure for containment of the gas.[162] Because storage is made more economical by using reservoirs of more than 1 billion cu m, the need to find large sites has become more urgent. The imminent exhaustion of several gas and oil fields in the Ukraine and Caucasus, however, will ease this shortage somewhat in the near future.

Numerous additional problems persist. Resources have been overextended because too many projects have been started at the same time, with few of them receiving adequate allocations of manpower and materials. Delivery of supplies to some sites has been delayed for up to a year.[163] Moreover, many new projects have been particularly hard hit by mismanagement and poor construction, with equipment or pipeline breakdowns dragging out construction and the beginning of operations.[164]

Capacity expansion at existing storage facilities also has lagged seriously. Of the 1,600 gas-injection wells at depleted fields available for storage use in 1975, only 700 (44 percent) had been put into operation.[165] In addition, gas processing units at several reservoirs have not been completed.

Despite these problems, gas storage will continue to grow through 1980. New facilities under construction in the Ukraine, Caucasus, Uzbek, and Moscow regions will raise total storage

capacity by several billion cu m. Storage in the Ukraine alone—where production is starting to decline—is planned to increase 8 billion cu m, up from 2.9 billion cu m in 1975.[166] If the obstacles described above persist, however, the national goal of an increase of 27 billion cu m in recoverable capacity by 1980 will not be reached. Even if it is, the Soviets will still not possess an adequate national storage system until sometime in the 1980s.

APPENDIX F

THE ORENBURG PROJECT

The most ambitious joint CEMA operation ever undertaken is the construction of a 2,750-km pipeline that will bring gas from the Orenburg field in the Urals to Eastern and Western Europe.[167] Begun in mid-1975, the project involves cooperation by six East European nations and the Soviet Union in laying a 1,420-mm line from the Orenburg gasfield, in the Urals, to the Soviet-Czechoslovak border. In return for their assistance, the six CEMA participants for 12 years will receive annually a total of 15.5 billion cu m of Orenburg gas. The pipeline, now called "Soyuz," is scheduled for completion in late 1978. Once the line reaches its full capacity of 28 billion cu m in 1980 or 1981, it may also be used to fulfill supply commitments to Western Europe.

The project as initiated in 1974 was estimated to cost $4 billion to $5 billion and to entail extensive participation by the six CEMA cosigners. Five of them (Czechoslovakia, Bulgaria, Hungary, East Germany, and Poland) were to construct parts of the pipeline, each financing and laying approximately 500 km of pipe and constructing related compressor stations. The trunkline as a whole is to be equipped with 22 compressor stations. Romania was to finance French construction of the third sulfur-removal unit at Orenburg itself, enabling the field to reach its peak capacity of nearly 45 billion cu m. Beginning in 1980, the five pipelaying countries are each to receive annually 2.8 billion cu m of gas; Romania is to receive 1.5 billion cu m.

The Orenburg project has relied heavily on Western imports. In addition to French installation of the Orenburg field equipment, [168] Moscow has probably obtained most of the approximately 1.7 million tons of required large-diameter pipe from Western companies. Equipment related to pipeline construction and operation has also been purchased from the West.[169] In the project's single largest purchase, the Soviets after year-long negotiations contracted with West Germany and Italy for the 158 turbine units needed in the line's compressor stations.[170]

A serious problem facing pipelaying progress is the CEMA participants' failure to send the required numbers of skilled laborers. By 1977, the five pipe-building nations had sent an estimated 12,000 to 14,000 workers,[171] less than one-half their original quota of 30,000 workers.[172] Only Poland was still scheduled to complete its entire pipeline section and compressor stations.[173] The others have arranged for lesser construction responsibilities, with compensating increases in their financial support of the project.[174] Romania, which had no labor commitment, is fulfilling its initial pledge of investment in the Orenburg field. To fill the labor gap, Soviet crews apparently have been taken off other pipelaying jobs and transferred to the Orenburg line. The more experienced Soviet workers may increase the pace of the line's construction, but their transfer may leave crews on other important pipelaying projects shorthanded.

Construction of the pipeline itself may be finished by the late-1978 deadline, although completion in early 1979 is more likely. The buildup of the line's compressor power may take longer than planned to reach full capacity. Lengthy negotiation for the compressor units has delayed complete Western delivery of the units

until late 1978. This probably will not give the Soviets time to transport and install all of them by January 1980. However, the Soviets should be able to complete enough stations by late 1978 or early 1979 to bring a little gas into Eastern Europe for ceremonial purposes. The Orenburg line will be able to satisfy the commitment to supply 15.5 billion cu m annually to Eastern Europe by 1981 and perhaps to fulfill some of Moscow's gas export contracts with Western Europe.

APPENDIX G

THE TRILATERAL TRADE AGREEMENT

Under a contract signed in late 1975, the Soviet Union will serve as a middleman in Iranian sale of gas to Europe. The 20-year agreement, [175] which will take full effect in 1984, stipulates that the USSR will:

(1) Import 17 billion cu m of Iranian gas annually.

(2) Use that gas for its own consumption, primarily in the increasingly gas-poor Caucasus.

(3) Export 15 billion cu m of its own gas to Western Europe and Czechoslovakia, probably via the Orenburg line (see appendix F) and the Central Asia–Center and Urengoy–Center trunkline systems.

Moscow will benefit considerably from the deal. The difference of 2 billion cu m between Soviet imports from Iran and exports to Europe will be considered a transit fee. The Soviets apparently will also receive an undisclosed amount of hard currency per each 1,000 cu m of gas delivered to the West European importers. [176] This latter fee could earn Moscow several billion dollars over the agreement's 20-year run.

Initial deliveries will begin in 1981. The gas will come from Iran's Kangan field and be piped 1,400 km along the second Iranian Gas Trunkline (IGAT-II) to the Soviet border at Astara. Western firms and the Soviets will aid Iran in the line's construction, [177] which was scheduled to begin in late 1977. Consisting of 1,220-mm and 1,420-mm pipe, IGAT-II in January 1981 is to begin operations considerably below capacity. Only a few billion cu m will be delivered to Western Europe in that year. As the trunkline reaches its capacity of 27 billion cu m, Czechoslovakia will begin receiving its share (3.6 billion cu m) in 1983 and the West European countries their full amount in 1984: West Germany (5.7 billion cu m), France (3.8 billion cu m); and Austria (1.86 billion cu m). Czechoslovakia, included in the agreement only in December 1976, [178] is being repaid in gas for building a new trunkline across its territory that will bring West Europe's share to the Austrian border. Iran itself intends to consume domestically 10 billion cu m of the gas annually transmitted by IGAT-II.

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APPENDIX H

LIQUEFIED NATURAL GAS

LNG exports could eventually add $2 billion to $3 billion annually to Soviet hard currency earnings under two proposed East-West ventures. However, LNG is unlikely to play a significant role in Soviet gas exports for at least another decade. Progress has been slow in negotiations for Western participation in developing liquefaction systems for export of gas from West Siberia and from the Soviet Far East. Talks, under way intermittently since 1973, have been hung up over LNG pricing, constraints on US Export-Import Bank financing of LNG facilities, and possible US Government limits on LNG imports. Given the long leadtimes required for installing the proposed LNG facilities, significant Soviet LNG exports probably could not begin until the late 1980s even if agreement on either proposal was reached within the next year.

Yakutsk

The most active of the two ventures proposed is one formally agreed upon in December 1974, whereby the United States, Japan, and the USSR would develop an LNG system using gas from deposits near Yakutsk in the Soviet Far East. US and Japanese backing of Soviet investment—originally estimated at $4 billion to $5 billion—would go toward (a) exploration and development of the Vilyuy field, (b) construction of a 4,350-km pipeline of 1,200- or 1,420-mm pipe, and (c) installation of a liquefaction plant near Ol'ga. [179] In return the Soviets over a 20-year period would ship 10 billion cu m of LNG to both Japan and the United States annually. [180] The arrangement would make the best use of Yakutsk gas, which is too far from major Soviet consuming centers to make pipeline transport economical.

Negotiations on the project have been moving at a low level, but progress has been made. In March 1976 Japan and a US consortium made loans of $25 million each for the exploration phase of the project. [181] Talks on initiation of the costly development phase, however, have been slowed by Export-Import Bank financing limitations and by the thus far indequate results from Soviet exploration of the Yakutsk deposits—reserves of only 800 billion cu m had been proved by mid-1978. [182] Until Yakutsk gas reserves reach a level deemed sufficient to justify a 20-year export agreement—reportedly 1 trillion cu m [183]—the Western concerns are unwilling to commit themselves to loaning additional sums for the project. [184] The venture's total cost is currently estimated at about $7 billion. [185]

North Star

Talks are in limbo on the North Star venture involving liquefaction of gas from the large Urengoy field in West Siberia. Originally proposed by a US consortium, North Star was to provide for annual delivery of 21 billion cu m of gas to the US east coast over a period of 25 years. [186] US credits were to provide for (a) gathering lines at Urengoy; (b) a 1,220-mm, 2,460-km pipeline bringing the gas to an ice-free port on the Kola Peninsula; (c) a liquefaction plant and auxiliary facilities at the port; and (d)

a fleet of 20 LNG tankers. [187] The total cost was estimated at $7 billion to $8 billion in mid-1970s' prices. [188]

No real move toward an agreement has been made. After 1975, when Congressional limitations on US Export-Import Bank credits to Moscow forced the US consortium to drop discussion of the project, a West European group picked up the negotiations in January 1976.[189] Under a revised proposal France, West Germany, and possibly the United Kingdom would provide the pipe, equipment, and financing. [190] If the plan were agreed upon, the European and US consortiums would divide the annual LNG deliveries of 21 billion cu m. However, the European group and Moscow have not yet hammered out a price. Exports of gas from Urengoy for the North Star project do not appear likely until the late 1980s and then only if agreement on the venture is reached within the next few years. In the absence of a guaranteed US market for Soviet LNG it is doubtful that the USSR would invest in liquefaction facilities because the Urengoy gas could be exported to Europe more expeditiously and at lower cost by pipeline, without liquefaction.

APPENDIX I

Major Natural Gas Pipelines[1]

Pipeline Route	Kilometers	Diameter (Millimeters)	Number of Lines	Maximum Capacity (Billion Cubic Meters per Year)	Comments
West Siberian systems					
Urengoy-Medvezh'ye-Punga-Vuktyl-Torzhok-Ivatsevichy-Uzhgorod	5,500	1,220-1,420	3	56	The "Northern Lights" system, built originally in the 1960s to transport gas from the Vuktyl Field, will link up with the Tyumen' Fields via two 1,420-mm Punga-Vuktyl lines. Four lines are planned between Vuktyl-Torzhok by 1980, with a potential capacity of 70 bcm, approximately 50 bcm of which is to be available for Tyumen' gas, 20 for Komi ASSR gas. Most of current capacity goes to Moscow and Leningrad regions.
Urengoy-Medvezh'ye-Punga-Nizhnaya Tura-Izhevsk-Moscow	2,600	1,220-1,420	2	40	The "Urengoy-Center" system, which until 1977 had carried all northern Tyumen' gas to the Urals and Moscow. Additions of 1,420-mm and 1,220-mm lines along the Punga-Nizhnaya Tura and Nizhnaya Tura Center sections will probably increase capacity to 75 bcm.
Urengoy-Vyngapur-Chelyabinsk	1,600	1,420	1	33	The "Urengoy-Chelyabinsk" system, which began contruction in late 1976. It will form the initial section of a multiline system extending through the central European USSR to the Czechoslovak border. Completion of the first line is scheduled for 1978-79 but capacity by 1980 probably will not reach projected maximum.
Nizhnevartovsk-Parabel'-Tomsk-Kemerovo-Novokuznetsk	1,100	1,020	1	10	Construction began in 1976 and is behind schedule but the line should reach full capacity by 1980. It will transport associated gas from the Samotlor Field to the Kuzbass region. A branch to Novosibirsk is also under construction.
Balyk-Nizhnevartovsk	200	NA	1	NA	Operational in 1976.
Soleninskoye-Messoyakha-Noril'sk	300	720-1,020	3	11	Northernmost gas pipeline in the world. Current capacity is 6.4 bcm; construction of third line began in 1976.
Vologda-Cherepovets-Leningrad	550	1,020-1,420	1	30	Branch of Northern Lights system; Vologda-Cherepovets section completed in 1975.
Central Asian systems					
Bukhara-Chelyabinsk	1,950	1,020	1	10	The "Central Asia-Urals #1" system, completed in 1964. Short section will be expanded to 1,220-mm in 1978.
Bukhara-Nizhniy Tagil	2,300	1,020	1	10	The "Central Asia-Urals #2" system, completed in 1966.
Bukhara-Moscow-Leningrad	3,200	1,020	1	10	"Central Asia-Center #1," completed in 1967.
Bukhara-Moscow	2,400	1,220	1	15	"Central Asia-Center #2," finished in 1970.
Okarem-Beynev-Ostrogozhsk	2,550	1,020-1,220	1	20	"Central Asia-Center #3"; to reach full capacity of 20 bcm in 1977.

Footnote at end of Table.

APPENDIX 1

Major Natural Gas Pipelines[1] (Continued)

Shatlyk-Khiva-Ostrogozhsk	2,600	1,420	1	40	"Central Asia-Center #4," completed in 1975. Two lines run from Shatlyk to Khiva where they are joined by Central Asia-Center lines #s 1 and 2.
Mubarek-Alma Ata	1,325	529-1,020	2	17	First line completed in 1970; second in 1975.
Bukhara-Tashkent-Chimkent	770	529- 720	1	2	Completed in 1959.
Mayskoye-Bayram Ali-Ashkhabad-Bezmein	500	529	1	2	Completed in 1970.
Mubarek-Kelif-Afghanistan	275	820	1	4	Completed in 1967.
Kelif-Dushanbe	300	NA	2	NA	First line completed in 1967; second in 1974.
Uzen-Shevchenko	150	520	1	2	Completed in 1967.
Samarkand-Leninabad-Kokand-Fergana-Kuvasai	475	520	1	2	First section, Kuvasai-Fergana, completed in 1959; Fergana-Leninabad completed in 1963; the Samarkand-Leninabad section became operational in 1964.
Palvantash-Changyrtash-Andizhan	200	NA	1	NA	Probably operational by mid-1960s.
Khodziabad-Fergana-Andizhan-Namangan-Kokand	425	NA	1	NA	Various sections completed during late 1950s and early 1960s; a branch also runs from Andizhan to Mailisu via Osh.
Urals systems					
Orenburg-Kremenchug-Uzhgorod	2,750	1,420	1	28	The "Orenburg Project," to be completed in late 1978 or early 1979; full capacity likely by early 1980s; a joint CEMA construction project which will bring gas from the Urals to the Czech border for export to Eastern and Western Europe.
Orenburg-Novopskov	1,200	1,220	1	12	Completed in 1976.
Dombarovsk-Orenburg	400	1,220	1	15	To link Central-Asia-Urals lines with Orenburg lines; construction began in 1976; began operation in 1977.
Tuymazy-Shkapovo-Ishimbay-Magnitogorsk	475	529	2	3	First line completed from Shkapovo in 1958; second line finished in 1966.
Nizhnaya Tura-Perm'	250	1,020	1	9	Completed in 1966; construction of a second line of 1,220-mm diameter extending to Kazan' and Gor'kiy is planned during 1976-80.
Minnebayevo-Kazan'	280	305-529	2	1.5	First line completed in 1954; second in 1963.
Kazan-Gor'kiy	375	305	1	0.5	Line completed in 1957.
Minnebayevo-Tuymazy-Ufa	260	250-355	1	0.5	Completed in 1953. A second Minnebayevo-Tuymazy line was completed in 1960.
Saratov-Moscow	790	305	2	0.5	Completed in 1946. A second line was built during 1965-70.
Buguruslan-Kuybyshev-Pukhvintsnevo	300	305	1	0.5	Completed in 1943.
Orenburg-Zainsk	500	1,020	1	8.5	Completed in 1972.
Orenburg-Kuybyshev	400	1,000	1	NA	Completed in 1974.
Mokrous-Kuybyshev-Tol'yatti-Ulyanovsk	600	529-820	1	3.5	Completed in 1970.
Saushinskaya-Log-Volgograd	125	529	1	1.5	Completed in 1957.
Kotlas-Kirov	360	720	1	3	Branch of Northern Lights line.
Chusavoy-Berezniki-Solikamsk	180	529	1	1.5	Operational in 1967.

Footnote at end of Table.

APPENDIX I

Major Natural Gas Pipelines[1] (Continued)

Ukraine systems					
Dashava-Bratislava (Czechoslovakia)	700	820	1	4	Known as the "*Bratsvo*" (brotherhood) line; completed in 1967 to allow expansion of gas exports in Eastern Europe.
Dolina-Dashava-Uzhgorod	200	820-1,420	2	29	Second *Bratsvo* line completed in 1975. A third line is under construction.
Dashava-Minsk-Ivatsevichi-Vilnyus-Riga	1,385	529-720-820	1	6.8	Completed in 1962.
Shebelinka-Bryansk	875	720	2	10	Completed in 1960.
Shebelinka-Dnepropetrovsk-Odessa	700	720	2	10	First line completed in 1966; second line opened in 1976.
Dashava-Kiev-Bryansk-Moscow	1,300	529	1	1.5	Completed in 1949. Second Dashava-Kiev line completed in 1959.
Kiev-Western Ukraine	550	1,020	2	16	First line built in 1970 to Kamenka-Bugskaya; second line to Dolina in 1975.
Belsk-Sumy-Shchors-Gomel-Minsk	725	425	1	NA	Completed in 1962.
Shebelinka-Kiev	500	1,020-1,420	3	23	First line completed in 1964; second in 1970; third in 1975.
Valday-Pskov-Riga	600	1,020	1	7	Completed in 1972.
L'vov-Ivano-Frankovsk-Chernovotsy	300	NA	1	2	Operational in 1961.
Odessa-Kishinev	180	NA	1	1	Operational 1967.
Razdel'naya-Izmail (to Bulgaria via Romania)	355	1,020	1	8.5	Operational in 1976.
Shebelinka-Slavyansk-Lisichansk-Lugansk	260	720	1	3.7	Operational in 1969.
Nikolayev-Kherson	75	720	1	4	Built in early 1960s.
Strelkovskoye-Dzhankoy-Simferopol	160	NA	1	NA	Operational in 1976.
Krasnodar'-Kerch-Simferopol-Sevastopol	575	820	1	NA	Built in early 1960s.
Poltava-Kremenchug-Krivoy Rog	275	720-1,020	1	8.5	Completed in 1967.
Shebelinka-Dnepropetrovsk	200	720-820	2	8	First line completed in 1957; second line in 1961.
Central systems					
Moscow Ring	420	820-1,020	2	20	First ring completed in 1963; second ring finished in 1976.
Saratov-Gor'kiy-Cherepovets	1,200	529-720-820	1	6	Completed in 1961.
Stavropol'-Moscow	1,275	720-1,020	2	10	First line completed in 1956; second in 1960.
Tallinn-Leningrad	350	229-529	2	3	Shale gas lines; first completed in 1948; second in 1963.
Serphukov-Leningrad	800	720-1,020	2	17	First line completed in 1959; second in 1968.
Moscow-Tula	180	529	1	1.5	Completed in 1954.
Shebelinka-Ostrogozhzk	250	1,020	1	8.5	Operational in 1961.
Ostrogozhsk-Gubkin	150	NA	2	NA	Line #1 completed in 1975; second line in 1976.
Rostov-Taganrog	80	720	2	8	First line finished in 1956; second completed in 1958.
Taganrog-Zhdanov	100	520-720	2	8	Completed in 1959.
Taganrog-Donetsk-Slavyansk	230	520-720	1	4	Completed in 1960.
Leningrad-Vyborg-Imatra-Finland	180	1,420	1	20	Operational in 1974.
Riga-Liepaja	180	NA	1	NA	Operational.
Panevezys-Klaipeda	200	NA	1	NA	Operational in 1968.
Roslavl-Smolensk-Dorogobuzh	320	NA	1	NA	Operational in 1966.
Gor'kiy-Vladimir-Moscow	350	820	1	6	Operational in 1967.

Footnote at end of Table.

APPENDIX I

Major Natural Gas Pipelines[1] (Continued)

Caucasus and Trans-Caucasus systems					
Ahwaz (Iran)-Astara (USSR)-Kazi Magomed	1,200	1,020	1	12	Known as the Iranian Gas Trunkline (IGAT I) system, it opened in late 1970 to allow importation of Iranian natural gas; 200 km of the line lies within the USSR. A second line, IGAT II, is under construction; it will use 1,220 and 1,420 pipe; initial operation is planned for 1981, reaching full capacity (27 bcm) by 1984.
Mozdok-Ordzhonikidze-Tbilisi	380	529-720	3	8	First and second lines built in 1963-64; a third line was under construction in 1975.
Karadag-Yerevan-Tbilisi	770	720-1,020-1,220	3	10	First line completed in 1960, second in 1970, third line was under construction in 1975.
Krasnodar'-Rostov-Lugansk-Serpukhov	1,200	820-1,020	2	30	Completed in 1962. A second line was built in the mid-1960s.
Stavropol'-Groznyy	425	529-720	1	4.8	Completed in 1959.
Karadag-Baku	50	529	1	1.5	Completed in 1956.
Karadag-Sumgait-Siazan	115	500-720	1	1.8	Completed in 1964. A second line runs from Sumgait to Siazan.
Far East systems					
Mastakh-Tas Tumus-Yakutsk-Pokrovsk-Bestyakh	500	529	1	1.5	Tas Tumus-Yakutsk completed in 1967; branches to Pokrovsk and Mastakh added in 1969 and 1972, respectively.

[1] Large-diameter pipelines, 520 millimeters (20.5 inches) or larger, and small-diameter lines at least 150 kilometers long.

APPENDIX J

STATISTICAL TABLES

Table J-1

Production of Natural Gas[1]

	Million Cubic Meters
1928	304
1929	330
1930	520
1931	845
1932	1,049
1933	1,063
1934	1,531
1935	1,806
1936	2,050
1937	2,179
1938	2,208
1939	2,531
1940	3,219
1941	3,463
1942	2,045
1943	1,852
1944	2,405
1945	3,278
1946	3,902
1947	4,830
1948	5,219
1949	5,396
1950	5,761

[1] Including associated gas. Source: Elliot, *Soviet Energy Balance*, p. 38.

Table J-2

Gas Production, 1950-77 and 1980 Plan

Billion Cubic Meters

	Total	Nonassociated	Associated [1]
1950	5.8	4.0	1.8
1951	6.3	4.1	2.2
1952	6.4	4.1	2.3
1953	6.9	4.5	2.4
1954	7.5	4.9	2.6
1955	9.0	5.9	3.1
1956	12.1	8.4	3.7
1957	17.6	14.3	3.3
1958	28.0	22.6	5.4
1959	35.3	28.8	6.5
1960	45.3	37.6	7.7
1961	59.0	50.4	8.6
1962	73.5	63.5	10.0
1963	89.8	77.7	12.1
1964	108.6	94.4	14.2
1965	127.7	111.2	16.5
1966	143.0	125.2	17.8
1967	157.4	138.6	18.8
1968	169.1	149.5	19.6
1969	181.1	159.5	21.6
1970	197.9	174.9	23.0
1971	212.4	187.4	25.0
1972	221.4	195.6	25.7
1973	236.3	209.8	26.5
1974	260.6	233.0	27.6
1975	289.3	260.7	28.6
1976	320.6	NA	NA
1977	346.0	NA	NA
1980[2]	435.0	390-395	40-45

[1] Gas extracted along with oil and then separated. Sources: A. K. Kortunov, *Gazovaya promyshlennost' SSSR*, Moscow (1967), p. 62; Brentz, *Ekonomika gazodobyvayushchey promyshlennosti*, pp. 33-34.

[2] Plan.

Table J-3

Allocation of Capital Investment by the Ministry of the Gas Industry

	1966-70		1971-75		1970		1975	
	Million Rubles [1]	Percent	Million Rubles [1]	Percent	Million Rubles [1]	Percent	Million Rubles [1]	Percent
Total	4,049.0	100.0	10,903.5	100.0	1,189.6	100.0	2,966.9	100.0
Geological exploration	63.3	1.6	335.0	3.1	10.9	0.9	78.0	2.6
Extraction	1,019.1	25.2	3,139.4	28.8	332.7	28.0	878.5	29.6
Development drilling	330.0	8.2	701.9	6.4	114.9	9.7	170.6	5.8
Field preparation	689.1	17.0	2,437.5	22.4	217.8	18.3	707.9	23.9
Pipeline transport	2,597.2	64.1	6,445.8	59.1	695.8	58.5	1,718.5	57.9
Natural gas processing	59.4	1.5	478.0	4.4	36.7	3.1	102.8	3.5
Underground storage	44.6	1.1	116.9	1.1	7.2	0.6	62.0	2.1
Machine building	61.5	1.5	131.4	1.2	22.7	1.9	57.2	1.9

[1] In current prices, as opposed to "comparable" prices, the Soviet pricing concept analogous to constant prices in the West. "Comparable" prices are deflated with an index based on a given year (until recently, 1967, and now 1975). They do include, however, some current factor prices (for example, for new types of machinery introduced after the base year). Source: Margulov, *Razvitiye gazovoy promyshlennosti*, p. 17.

Table J-4

Value of Fixed Capital, Ministry of the Gas Industry

	1970		1971		1972		1973		1974		1975		1975 Increase Over 1970	Average Annual Increase, 1971-75
	Million Rubles [1]	Percent	Million Rubles [1]	Percent	Million Rubles [1]	Percent	Million Rubles [1]	Percent	Million Rubles [1]	Percent	Million Rubles [1]	Percent	(Percent)	(Percent)
Total	6,207.1	100.0	7,084.4	100.0	8,121.9	100.0	9,457.3	100.0	11,090.4	100.0	13,720.0	100.0	121.0	17.2
Drilling	81.0	1.3	92.0	1.3	118.0	1.5	122.0	1.3	134.0	1.3	141.0	1.0	74.1	11.7
Extraction	903.6	14.6	1,116.2	15.8	1,295.4	15.9	1,537.1	16.3	1,952.6	17.6	2,441.0	17.8	170.1	22.0
Pipeline transport	4,824.0	77.7	5,423.0	76.7	6,209.0	76.4	7,219.1	76.3	8,290.0	74.7	10,213.0	74.4	111.7	16.2
Natural gas processing	56.4	0.9	79.4	1.1	91.4	1.1	103.7	1.1	154.8	1.4	280.0	2.0	396.5	37.8
Machine building	112.8	1.8	111.6	1.6	123.3	1.5	129.7	1.4	137.6	1.2	152.0	1.1	34.8	6.1
Other	229.3	3.7	262.2	3.7	284.8	3.5	345.7	3.7	421.9	3.8	493.0	3.6	115.0	16.5

[1] In current prices. Although the lack of data in constant prices prevents accurate comparisons, the table is useful for inferring trends because of (a) the relatively short time period involved and (b) the magnitude of the increase in value of fixed capital stock. These two considerations suggest that price inflation did not account for most of the increased value. Source: Margulov, *Razvitiye gazovoy promyshlennosti*, pp. 17-18.

Table J-5

Share of Major Fuels in Total Fuels Production [1]

Percent

	Gas [2]	Oil [3]	Coal
1955	2.4	21.1	64.8
1956	3.0	23.3	63.2
1957	4.0	24.5	61.2
1958	5.5	26.3	58.8
1959	6.4	28.1	56.1
1960	7.9	30.5	53.9
1961	9.7	32.4	50.5
1962	10.9	34.2	48.8
1963	12.4	34.8	45.9
1964	13.9	35.1	44.2
1965	15.5	35.8	42.7
1966	16.5	36.7	40.7
1967	17.2	37.8	39.4
1968	17.9	39.2	38.0
1969	18.3	39.9	37.3
1970	19.1	41.1	35.4
1971	19.5	41.8	34.6
1972	19.5	42.3	34.0
1973	19.9	43.2	33.0
1974	20.8	43.8	32.1
1975	21.8	44.1	30.8
1976	23.1	45.0	29.0
1977 [4]	24.0	45.0	28.0

[1] Sources: *Narodnoye khozyaystvo SSSR*, various issues.
[2] Natural and associated.
[3] Including gas condensate.
[4] CIA estimate.

Table J-6

Natural Gas Production, Trade, and Apparent Consumption[1]

Billion Cubic Meters

	Production	Net Exports[2]	Apparent Consumption
1958	28.0	0.2	27.8
1960	45.3	0.2	45.1
1961	59.0	0.3	58.7
1962	73.5	0.3	73.2
1963	89.8	0.3	89.5
1964	108.6	0.3	108.3
1965	127.7	0.4	127.3
1966	143.0	0.8	142.2
1967	157.4	1.1	156.3
1968	169.1	0.2	168.9
1969	181.1	0.6	180.4
1970	197.9	−0.3	198.2
1971	212.4	−3.6	215.9
1972	221.4	−6.0	227.3
1973	236.3	−4.6	240.9
1974	260.6	2.1	258.5
1975	289.3	6.9	282.4
1976	320.6	14.0	306.6
1980	435.0[3]	40.9	394.1

[1] Sources: *Vneshnyaya torgovlya* and *Narodnoye khozyaystvo SSSR*, various issues.
[2] A minus indicates net imports.
[3] Soviet plan.

Table J-7

Gas Consumption by Region

Billion Cubic Meters

Region	1960	1965	1970	1975
USSR[1]	**44.4**	**120.3**	**179.1**	**239.5**
RSFSR	23.9	75.6	117.3	160.5
Of which:				
Northwest	1.8	6.6	9.5	13.4
Cenrtral	6.5	22.5	32.0	38.5
Central-Black Earth	0.9	2.7	4.6	5.6
Volga	8.8	18.0	22.9	36.5
North Caucasus	4.4	11.2	15.3	18.2
Urals	0.5	10.2	26.2	38.7
Ukrainian SSR	14.6	34.6	49.6	58.3
Belorussian SSR	0	2.3	2.9	4.0
Transcaucasus	5.9	7.8	9.3	16.7

[1] Excluding Georgian SSR, Azerbaijan SSR, Armenian SSR. The USSR total would still be smaller than the "apparent consumption" totals presented in table J-6, because the data presented here do not include losses and use by the gas industry itself. The exclusion of these latter two categories distinguishes "actual consumption"—presented here—from "apparent." Source: Margulov, *Razvitiye gazovoy promyshlennosti*, p. 8.

Table J-8

Gas Consumption, by Economic Sector [1]

Sector	Billion Cubic Meters						Percent of Total Consumption in 1958	Percent of Total Consumption in 1975
	1958	1960	1965	1968	1970	1975		
USSR	27.8	45.1	127.3	168.9	198.2	282.4	100	100
Household-municipal	2.9	5.7	14.9	21.1	25.3	34.0	10	12
Industry	14.3	25.4	73.5	96.8	109.1	156.1	51	55
Chemicals	0.3	1.9	6.2	10.7	12.9	22.8	1	8
Metallurgy	1.7	5.1	18.4	27.4	30.3	41.1	6	15
Machinery and metalworking	1.8	3.4	12.8	16.2	19.1	24.2	6	9
Construction materials and construction	2.4	4.5	14.0	17.5	19.3	26.5	9	9
Oil and gas [2]	5.6	6.0	12.4	13.6	10.6	20.5	20	7
Light industry	0.2	0.6	2.0	2.2	2.5	3.8	1	1
Food industry	0.6	1.2	4.2	5.7	6.1	8.2	2	3
Other	1.7	2.7	3.5	3.5	8.3	9.0	6	3
Electric power plants	9.6	12.2	35.7	44.1	52.7	67.8	35	24
Transport	0.1	0.2	0.4	0.6	0.7	1.3	Negl	Negl
Agriculture	Negl	0.1	0.2	0.4	0.7	1.9	Negl	1
Other [3]	0.9	1.5	2.6	5.9	9.2	21.3	3	8

[1] Sources: Robert W. Campbell, *The Economics of Soviet Oil and Gas*, Baltimore (1968), p. 214; *Review of Sino-Soviet Oil* (May 1970), p.18; Margulov, *Razvitiye gazovoy promyshlennosti*, p. 14.

[2] Including gas used for production of carbon black.

[3] Represents primarily losses and use by the gas industry (e.g., for the operation of compressor stations on gas trunklines). Total for USSR therefore equals the "apparent consumption" data presented in table J-6.

Table J-9

Share of Natural Gas in Boiler and Furnace Fuel, by Region[1]

Percent

Region	1962	1965	1970
USSR	14.9	21.3	27.9
European regions	22.0	26.4	32.2
North-West	9.2	16.9	20.9
Baltic	3.4	11.0	10.7
Belorussia	15.8	16.6	18.2
Central Region	25.7	32.3	37.2
Central Chernozem	14.1	19.1	24.3
Volga-Viatka	15.5	21.8	22.2
North Caucasus	33.0	47.0	46.5
Volga Region	26.9	33.9	29.8
Transcaucasus	46.6	41.3	38.6
Ukraine	21.3	29.2	35.0
Urals	1.7	15.6	37.8
Eastern regions	2.6	5.5	12.1
West Siberia	0	0	0.7
East Siberia	0	0	1.4
Far East	2.1	2.4	4.7
Kazakhstan	2.3	2.8	12.6
Central Asia	18.0	37.7	57.0

[1] Source: A. E. Probst and Ya. A. Mazover, eds., *Razvitive i razmeshchenive toplivnoy promyshlennosti* (1975).

Table J-10

Growth of Gas Reserves (A + B + C_1) and Reserves/Production Ratio [1]

	Billion Cubic Meters		
	Reserves (End of Year)	Production	Reserves/ Production
1955	692.4	9.0	76.9
1956	862.3	12.1	71.3
1957	1,095.6	17.6	62.2
1958	1,584.8	28.0	56.6
1959	2,202.4	35.3	62.4
1960	2,336.1	45.3	51.6
1961	2,547.4	59.0	43.2
1962	2,786.5	73.5	37.9
1963	3,061.6	89.8	34.1
1964	3,219.7	108.6	29.6
1965	3,563.9	127.7	27.9
1966	4,381.5	143.0	30.6
1967	7,753.0	157.4	49.3
1968	9,422.5	169.1	55.7
1969	12,085.9	181.1	66.7
1970	15,750.1	197.9	79.6
1971	17,992.9	212.4	84.7
1972	19,530.9	221.4	88.2
1973	22,413.6	236.3	94.9
1974	24,579.0	260.6	94.3
1975	25,800.0	289.3	89.2
1976	28,000.0	320.6	87.3

[1] For an explanation of what is included in the reserves categories (A + B + C_1), see notes to table 2, above. Sources (reserves data): for 1957-66, Kortunov, *Gazovaya promyshlennost' SSSR*, p. 35; for 1967, *Gazovaya promyshlennost'*, no. 1 (1968), pp. 13-18; for 1970, *Oil and Gas Journal* (7 September 1970), p. 51; for 1972, *Oil and Gas Journal* (22 January 1973), p. 64; for 1955-56, 1971, and 1973, Brentz, *Ekonomika gazodobyvayushey promyshlennosti*, p. 25; for 1974, *Oil and Gas Journal* (19 July 1976), p. 42; for 1975, Margulov, *Razvitiye gazovoy promyshlennosti*, p. 5; for 1976, *Geologiya bureniye i razrabotka gazovykh mestorozhdenii*, no. 4 (1977), p. 3. Source (production data): *Narodnoye khozyaystvo SSSR*, various issues.

Table J-11

Natural Gas Reserves (A + B + C_1) of Producing Regions [1]

Billion Cubic Meters, Beginning of Year

Region	1951	1956	1960	1965	1966	1967	1968	1971	1973	1974
USSR	**173.0**	**692.4**	**2,202.4**	**3,219.7**	**3,563.9**	**4,381.5**	**7,753.0**	**15,750.1**	**19,530.9**	**22,413.6**
RSFSR	89.2	450.8	972.3	1,472.8	1,693.3	2,380.6	5,525.2	12,316.1	15,796.9	18,102.2
Komi ASSR	20.8	21.2	18.1	18.4	38.3	73.7	136.2	405.6	439.4	367.1
Bashkir ASSR	0	0.4	23.1	18.4	30.3	44.1	46.2	54.5	50.5	58.2
Perm' Oblast	0	0	0	11.1	24.2	34.2	39.2	40.8	56.5	61.5
Kuybyshev Oblast	3.1	6.7	4.6	9.0	11.1	8.1	8.0	4.1	3.9	3.4
Orenburg Oblast	4.3	5.1	16.9	26.1	25.3	30.0	29.4	1,124.9	1,657.3	2,108.0
Saratov Oblast	21.3	53.1	66.9	74.0	70.8	68.1	72.1	59.4	57.1	62.2
Volgograd Oblast	6.4	47.5	141.6	110.4	89.5	92.7	91.0	85.7	79.3	77.3
Astrakhan Oblast and Kalmytskaya ASSR	0	3.9	11.6	48.6	46.9	17.3	18.7	20.4	17.6	16.4
Rostov Oblast	0	0	0	5.2	4.0	4.0	4.0	8.9	7.9	9.3
Krasnodar' Kray	0	75.6	359.4	458.9	465.3	427.6	419.4	89.7	255.8	256.0
Stavropol' Kray	26.8	225.7	249.6	251.2	234.4	228.9	222.1	198.6	180.9	171.3
Dagestan ASSR	0.5	0.1	0.1	26.4	42.7	53.4	63.1	35.0	28.7	31.2
Checheno-Ingush ASSR	4.9	2.7	2.0	8.6	8.6	8.5	8.5	8.3	5.8	8.2
Sakhalin Oblast	1.1	4.7	7.4	44.4	48.8	57.4	70.1	57.5	59.6	68.2
Tyumen' Oblast	0	4.1	50.2	300.3	400.8	895.8	3,850.4	9,252.3	11,797.4	13,749.5
Krasnoyarsk Kray	0	0	0	0	0	0	5.0	149.8	280.1	302.9
Tomsk/Novosibirsk Oblast	0	0	0	15.1	54.3	107.7	182.7	231.2	247.2	256.3
Irkutsk Oblast	0	0	0	20.5	20.5	20.5	20.5	12.9	12.9	12.9
Yakutsk ASSR	0	0	20.8	26.1	77.5	208.6	238.6	259.5	234.5	316.2
Ukraine SSR	70.3	148.7	544.8	643.5	655.2	636.5	663.2	810.0	848.4	868.7
Azerbaijan SSR	9.1	52.2	115.7	60.5	53.9	46.2	45.2	80.3	97.0	122.6
Kazakh SSR	0	0	1.2	41.8	91.7	131.8	173.8	177.3	165.9	167.6
Uzbek SSR	4.4	4.8	544.2	697.6	666.7	663.6	690.1	796.8	913.7	949.6
Turkmen SSR	0	35.5	13.1	282.2	376.4	486.5	605.6	1,522.3	1,963.7	2,158.6
Tadzhik SSR	0	0.3	3.4	9.2	12.8	20.3	32.1	31.7	29.5	29.0
Kirgiz SSR	0	0.1	7.7	12.1	13.9	16.0	17.8	15.6	15.8	15.3

[1] Sources: Brentz, *Ekonomika gazodobyvayushchey promyshlennosti*, p. 24; Kortunov, *Gazovaya promyshlennost' SSSR* (1967), p. 35; and *Gasovaya promyshlennost'*, no. 1 (1968).

Table J-12

Results of Exploratory Drilling

	Exploratory Drilling [1] (Thousand Meters)	Additions to Reserves (A + B + C_1) (Billion Cubic Meters)	Reserves of Gas Added per Meter Drilled (Thousand Cubic Meters)
1956	315	182	577.8
1957	602	251	416.9
1958	746	517	693.0
1959	918	653	711.3
1960	1,032	179	173.5
1961	1,500	270	180.0
1962	1,618	313	193.5
1963	1,734	365	210.5
1964	1,804	267	148.0
1965	1,942	474	244.1
1966	2,260	959	424.3
1967	2,514	3,529	1,403.7
1968	1,392	1,839	1,321.1
1969	2,606	2,844	1,091.3
1970	1,853	3,862	2,084.2
1971	2,826	2,455	868.7
1972	2,763	1,759	636.6
1973	2,839	3,119	1,098.6
1974	2,851	2,426	850.9
1975 [2]	2,944	1,510	512.9

[1] Drilling done by the Ministry of the Gas Industry and the Ministry of Geology. The latter ministry does exploratory drilling for both oil and gas.

[2] Estimated.

Table J-13

Natural Gas Production, by Region

Billion Cubic Meters

	USSR	West Siberia	Orenburg Oblast	Komi ASSR	Central Asia	Ukraine	Caucasus	Other
1960	45.3	0	0.5	0	0.8	14.3	18.4	11.3
1961	59.0	0	NA	0	1.5	20.6	22.0	14.9
1962	73.5	0	NA	0	2.5	26.2	28.1	16.7
1963	89.8	0	NA	0	3.4	31.6	32.7	22.1
1964	108.6	0	NA	0	10.2	35.6	37.8	25.0
1965	127.7	0	0.6	0	17.9	39.4	43.6	26.2
1966	143.0	0.6	NA	0.6	24.1	43.6	45.0	29.1
1967	157.4	5.2	NA	0.6	29.4	47.4	45.5	29.2
1968	169.1	8.2	NA	0.6	34.8	50.9	45.0	29.6
1969	181.1	9.1	NA	1.9	39.8	55.4	42.9	32.0
1970	197.9	9.2	0.8	6.5	48.0	60.9	45.2	27.2
1971	212.4	9.3	3.0	10.0	54.1	64.7	41.1	30.2
1972	221.4	11.4	5.0	13.0	59.5	67.2	35.9	29.4
1973	236.3	15.8	7.0	16.0	71.5	68.2	32.4	25.4
1974	260.6	21.8	10.5	17.0	82.5	68.3	28.5	32.0
1975	289.3	36.8	19.6	20.0	94.0	68.7	25.8	24.4
1976	320.6	44.0	31.4	21.0	104.5	68.7	24.2	26.8
1980 [1]	420.0	140.0	45.0	22.0	112.0	50.0	21.0	30.0
1985 [1]	560.0	300.0	45.0	20.0	100.0	30.0	15.0	50.0

[1] CIA projections.

Table J-14

Major Gas-Producing Regions [1] and Their Share of Total Soviet Gas Production

Region	1960		1965		1970		1975	
	Billion Cubic Meters	Percent	Billion Cubic Meters	Percent	Billion Cubic Meters	Percent	Billion Cubic Meters	Percent
USSR [2]	45.3	100.0	127.7	100.0	197.9	100.0	289.3	100.0
Ukraine SSR	14.3	31.5	39.4	31.0	60.9	31.0	68.2	23.6
Turkmen SSR	0.2	0.9	1.2	0.9	13.1	6.6	52.3	18.1
Uzbek SSR	0.4	1.0	16.5	13.0	32.1	16.2	37.1	13.0
Tyumen' Oblast	Negl	Negl	Negl	Negl	9.2	4.7	35.5	12.3
Orenburg Oblast	0.5	1.0	0.6	0.4	1.3	0.7	20.1	7.0
Komi ASSR	1.0	2.2	0.8	0.7	6.8	3.4	18.5	6.4
Stavropol' Kray	8.2	18.0	15.3	12.0	16.4	8.3	11.4	4.0
Azerbaijan SSR	5.8	13.0	6.2	4.8	5.5	3.0	9.3	3.2
Krasnodar' Kray	5.1	11.2	23.1	18.1	24.7	12.5	7.9	2.7
Volgograd Oblast	2.6	5.6	7.1	5.5	4.0	2.0	2.9	1.0
Saratov Oblast	2.5	5.6	6.4	5.0	3.4	1.7	1.0	0.3

[1] Regional data do not include natural and associated gas produced by the Ministry of the Oil Industry.
Source: Margulov, *Razvitiye gazovoy promyshlennosti*, pp. 28-39.
[2] Sum of regional production is less than USSR total.

Table J-15

Natural Gas Production, by Union Republic [1]

Million Cubic Meters

	USSR	RSFSR	Ukraine	Azerbaijan	Uzbek	Turkmen	Kazakhstan	Tadzhik	Kirgiz
1960	45,303	24,412	14,286	5,841	447	234	39	NA	41
1961	58,981	30,641	20,585	6,304	1,014	243	46	NA	148
1962	73,525	38,274	26,158	6,605	2,033	254	46	NA	155
1963	89,832	48,232	31,564	6,627	2,989	255	40	NA	126
1964	108,566	56,579	35,645	6,122	9,321	693	37	NA	146
1965	127,666	64,257	39,362	6,180	16,474	1,157	29	52	155
1966	142,962	69,042	43,617	6,173	22,566	1,265	46	90	163
1967	157,445	74,781	47,443	5,771	26,638	2,226	83	245	256
1968	169,101	78,347	50,942	4,993	28,988	4,843	321	366	291
1969	181,121	80,993	55,403	4,938	30,769	7,535	680	438	341
1970	197,945	83,321	60,877	5,521	32,094	13,107	2,092	388	367
1971	212,398	87,483	64,669	5,822	33,653	16,899	2,747	447	383
1972	221,386	87,400	67,236	6,880	33,739	21,312	3,525	498	395
1973	236,326	87,841	68,161	8,399	37,104	28,645	4,847	520	396
1974	260,553	100,046	68,318	9,151	37,064	39,272	5,372	496	323
1975	289,268	116,667	68,700	9,890	36,500	51,776	5,000	410	325
1976	320,600	136,000	68,700	10,989	36,000	62,600	5,200	400	330

[1] USSR total is sometimes greater than sum of Republic production because of a residual not identified in Soviet statistics. Source: *Narodnoye khozyaystvo SSSR*, various issues.

Table J-16

Output/Capital Ratios for Gas Extraction in the Ministry of the Gas Industry [1]

Cubic Meters/Ruble [2]

Gas Production Association	1971	1972	1973	1974	1975
Gas Ministry	163	134	121	106	96
Turkmen	345	295	267	232	174
Uzbek	381	228	223	183	163
Ukraine	187	154	149	130	113
Orenburg	123	75	40	91	94
Nadym [3]	0	66	104	97	90
Stavropol'	199	151	124	98	77
Komi	167	110	91	74	67
Yakutsk	54	17	25	30	24
Noril'sk	35	32	30	22	20

[1] Source: *Ekonomika gazovoy promyshlennosti*, no. 1 (1977), p. 5.
[2] In current prices, excluding a capital charge.
[3] Data refer primarily to Medvezh'ye field.

Table J-17

Economic Data From Selected Gas Production Associations [1]

Production Association	Gas Production (Billion Cubic Meters [2])	Share of USSR Production (Percent)	Total Gas Wells	Active Wells	Midyear Value of Capital Stock (Million Rubles)	Output/Capital Ratio [3]	Average Cost of Extraction [4] (Rubles/Thousand Cubic Meters)
Ukraine							
1970	55.0	28	1,142	960	308.8	1.08	0.48
1975	58.5	20	1,438	1,257	515.8	0.70	1.07
Turkmen							
1970	11.8	6	84	55	34.0	2.09	0.35
1975	47.0	16	299	260	269.2	1.05	0.73
Uzbek							
1970	31.5	16	393	276	97.0	2.04	0.23
1975	36.6	13	533	412	219.4	1.00	1.08
Tyumen'							
1970	9.2	5	84	53	84.7	0.65	0.95
1975	33.5	12	181	153	407.0	0.51	1.46
Orenburg							
1970	0.8	Negl	20	6	8.1	0.64	1.29
1975	18.3	6	174	136	192.4	0.59	1.59
Kuban (Krasnodar')							
1970	22.5	11	580	426	179.3	0.79	0.91
1975	5.8	2	818	587	201.5	0.18	5.47
Komi							
1970	6.2	3	33	22	34.6	1.25	1.17
1975	17.8	6	102	78	283.5	0.41	1.70
Stavropol'							
1970	15.7	8	757	574	83.4	1.14	0.44
1975	10.5	4	1,089	935	139.8	0.46	1.54

[1] Source: Margulov, *Razvitiye gazovoy promyshlennosti*, pp. 29-38.
[2] The actual total for a region may exceed that for the association itself.
[3] Rubles of gas per ruble of fixed reproducible assets in current prices (excluding transmission lines).
[4] In current prices. Does not include a capital charge.

Table J-18

Average Annual Output per Gas Well [1]

Million Cubic Meters

	USSR	Turkmen SSR	Tyumen' Oblast	Komi ASSR	Uzbek SSR	Khar'kov Oblast (Ukraine)	Stavropol' Kray	Krasnodar' Kray
1960	42.7	0	0	6.5	55.3	159.0	106.0	56.7
1965	58.7	0	0	3.7	133.0	133.2	77.8	74.3
1967	55.2	107.7	179.6	4.0	115.0	105.0	63.5	63.7
1968	52.6	145.0	235.1	4.5	103.0	95.6	50.4	59.0
1969	47.8	166.1	202.0	15.2	97.4	83.2	33.2	52.5
1970	47.8	213.9	169.3	53.9	99.4	83.2	27.4	44.5
1971	45.4	204.5	152.1	83.5	93.2	77.1	22.5	32.8
1972	44.2	176.0	143.8	101.4	83.2	72.5	19.9	23.5
1973	44.6	188.1	158.1	136.2	85.0	69.3	16.6	16.3

[1] Brentz, *Ekonomika*, p. 110.

Table J-19

Length of Gas Collection Pipeline Networks, [1] End of Year

	Kilometers
1960	2,528
1961	2,544
1962	2,982
1963	3,082
1964	3,898
1965	4,427
1966	4,459
1967	5,673
1968	8,219
1969	9,692
1970	10,964
1971	11,232
1972	11,455
1973	12,587

[1] Pipelines used for intrafield collection of gas in preparation for transport via main trunklines to consuming centers. Source: Brentz, *Ekonomika gazodobyvayushchey promyshlennosti*, p. 112.

Table J-20

Development of Soviet Trunkline System

	Total Length [1] (Thousand Kilometers)	Average Length of Transport [2] (Kilometers)	Commercial Gas Transported by Trunkline [3] (Billion Cubic Meters)	Commercial Gas Transported as a Share of Gas Output (Percent)	Cost of Transport via Trunkline [4] (Rubles/Thousand Cubic Meters)	Output/ Capital Ratio for Trunkline Transport [5] (Cubic Meters/Ruble) [6]
1958	12.2	543	13.4	48	226	NA
1959	16.5	570	21.0	59	223	NA
1960	21.0	589	32.8	72	221	35.4
1961	25.3	601	41.9	71	207	37.9
1962	28.5	611	53.6	73	194	41.0
1963	33.0	616	68.6	76	159	46.4
1964	37.1	644	87.7	81	160	47.3
1965	42.0	656	112.1	88	168	46.2
1966	47.4	678	128.8	90	164	44.6
1967	52.6	744	143.3	91	167	41.1
1968	56.1	864	155.1	92	188	38.2
1969	63.2	909	166.0	92	190	38.7
1970	67.5	917	181.5	92	201	37.1
1971	71.5	964	209.8	99	NA	36.0
1972	77.7	1,004	219.9	99	NA	33.1
1973	83.5	1,051	231.1	98	NA	30.2
1974	92.1	NA	245.7	94	NA	29.6
1975	99.2	1,285	279.2	96	304	26.5

[1] Sources: for 1958-66, Kortunov, *Gazovaya promyshlennost' SSSR*, pp. 94, 100; for 1967-75, *Narodnoye khozyaystvo SSSR*, various issues.

[2] Sources: for 1958-59, Kortunov, p. 94; for 1960-73, Khaskin, *Osnovnyye fondy gazovoy promyshlennosti*, p. 45; for 1975, Margulov, *Razvitiye gazovoy promyshlennosti*, p. 45.

[3] Sources: for 1958-74, *Narodnoye khozyaystvo SSSR*, various issues; for 1975, Margulov, p. 40.

[4] Sources: for 1958-68, Kortunov, p. 103; for 1969, *Review of Sino-Soviet Oil* (September 1970), p. 11; for 1970 and 1975, Margulov, p. 49.

[5] Sources: for 1960-69, Khaskin, p. 45; for 1970-75, Margulov, p. 15.

[6] In constant factor prices. Costs exclude, in part, full charge for use of capital.

Table J-21

Distribution of Major Gas Trunklines, by Size [1]

	Total Length (Kilometers)	Average Diameter (Millimeters)	1,420 mm	1,220 mm	1,020 mm	820 mm	720 mm	630 mm	529 mm	Other
			Kilometers							
1960	20,983.2	553	0	0	670.5	2,263.6	6,164.4	64.3	4,091.7	7,728.7
1961	25,328.9	574	0	0	1,276.6	3,130.6	7,413.4	64.3	5,099.6	8,344.4
1962	28,492.1	581	0	0	2,020.0	3,155.8	8,267.1	64.0	5,763.1	9,221.1
1963	33,032.7	605	0	0	3,703.0	3,382.0	9,301.1	73.0	7,195.0	9,378.6
1964 [1]	36,908.5	614	0	0	5,104.0	3,728.0	9,764.0	73.0	7,820.0	10,419.5
1965 [1]	42,279.2	628	0	0	7,528.0	4,014.0	10,460.0	120.0	8,268.0	11,889.2
1966 [1]	47,550.1	642	0	0	10,111.9	4,380.9	10,739.1	120.0	9,456.0	12,742.2
1968	56,100.0	654	0	521.4	13,532.4	4,746.7	11,749.7	106.1	10,627.4	14,815.5
1970	67,500.0	815	0	3,811.0	15,884.2	5,023.4	12,911.4	105.4	12,644.5	17,120.1
1971	71,500.0	817	0	4,393.0	16,926.3	5,537.3	13,184.5	219.4	13,582.6	17,656.9
1972	77,700.0	823	908.2	6,448.7	17,995.2	5,565.9	13,865.9	219.4	14,413.3	18,283.4
1973	83,500.0	914	1,570.7	8,874.5	18,500.0	5,977.7	14.176.0	209.4	15,075.0	19,116.7
1975	99,200.0	1,012	3,552.0	15,086.0	20,647.0	7,016.0	15,074.0	142.0	16,225.0	21,458.0
1980 [2]	134,600.0	1,082	15,000.0	18,230.0	26,050.0	7,155.0	14,265.0	NA	NA	53.900.0 [3]

[1] The sum of Soviet published data for pipelines of various sizes does not agree precisely with Soviet published data for national totals in the years 1964-66. Hence the discrepancy between data shown above and in table J-20. Sources: for 1960-66, Gal'perin, *Razvitiye i perspektivy transporta gaza*, p. 33; for 1968, *Review of Sino-Soviet Oil* (June 1970), p. 18; for 1971-73, Khaskin *Osnovnyye fondy gazovoy promyshlennosti*, p. 59; for 1970 and 1975, Margulov, *Razvitiye gazovoy promyshlennosti*, p. 13; for 1980, *Ekonomika gazovoy promyshlennosti*, no. 7 (1976), p. 30, and *Ekonomicheskaya gazeta*, no. 6 (1977), p. 2.

[2] Plan total; lengths by size are estimated.

[3] Including 630 mm and 529 mm.

Table J-22

Gas Storage Capacities [1]

	1960	1965	1970	1971	1972	1973	1974	1975	Plan 1980
	Units								
Number of underground storage sites	4	10	15	15	16	18	25	25	35
	Billion Cubic Meters								
Total storage capacity	0.7	5.2	12.3	14.1	16.0	19.9	30.8	39.5	68.6
Volume of gas in storage	0.4	3.6	10.1	12.0	13.7	18.3	30.8	39.5	68.6
Amount recoverable	0.3	2.4	6.0	6.2	7.2	8.0	11.0	18.3	45.0
Amount injected	0.2	1.8	5.5	5.6	5.8	7.8	10.4	14.3	30.7
Amount withdrawn	0.1	1.0	3.6	5.0	4.7	6.4	NA	8.6	NA
Net additions	0.1	0.8	1.9	0.6	1.1	1.4	NA	5.7	NA

[1] The relationships among the line entries in this table are in some cases inscrutable. Except for "Net additions," data are taken from the Soviet literature lacking explanatory notes. "Total storage capacity" is the maximum volumetric size of the storage reservoirs. "Volume of gas in storage" is apparently a function of the number and types of storage sites in the inventory and not a function of new additions as one might expect. As depleted fields are converted and added to the inventory of storage reservoirs, gas previously left behind in these fields as unrecoverable is apparently added to the "Volume of gas in storage." An unknown percentage of these additions becomes recoverable—and is reflected in "Amount recoverable"—as reservoirs pressures are increased during the injection of gas into storage. "Net additions" is the excess of gas stored (injected) over gas withdrawn. Source: Orudzhev, *Gazovaya promyshlennost'*, pp. 70-71.

Table J-23

Capacity of Gas Compressor Stations [1]

	Number of Compressor Stations	Aggregate Capacity (Thousand Kilowatts)	Compressor Station Power per 100 km of Pipeline (Thousand Kilowatts)
1959	18	130.2	0.79
1960	21	256.7	1.22
1961	28	564.7	2.23
1962	37	910.2	3.20
1963	52	1,190.0	3.60
1964	71	1,638.8	4.17
1965	81	1,868.8	4.42
1966	85	2,069.0	4.35
1967	96	2,460.0	4.66
1968	119	2,990.7	5.38
1969	124	3,077.3	4.97
1970	130	3,400.7	5.15
1971	136	3,873.7	5.48
1972	154	4,348.3	5.64
1973	180	5,309.8	6.49
1974	222	7,000.0	7.60
1975	286	8,000.0	8.13
1976 [2]	328	9,800.0	9.42

[1] Sources for 1960-73, Khaskin, *Osnovnyye fondy gazovoy promyshlennosti*, p. 17; for 1974, JPRS, no. 66236 (28 November 1975); for 1976, Margulov, *Razvitiye gazovoy promyshlennosti*, p. 9; for 1976, *Gazovaya promyshlennost'*, no. 3 (1976), pp. 1-3.

[2] Plan.

Table J-24

Aggregate Trade in Natural Gas [1]

	Exports								Imports			Net Trade [2]
	Total			Eastern Europe		Western Europe						
	Million Cubic Meters	Percent of Production	Million Rubles	Million Cubic Meters	Million Rubles	Million Cubic Meters	Million Rubles	Million US$	Million Cubic Meters	Percent of Apparent Consumption	Million Rubles	Million Cubic Meters
1960	242	0.5	1.7	242	1.7	0	0	0	0	0	0	242
1961	272	0.5	1.9	272	1.9	0	0	0	0	0	0	272
1962	300	0.4	2.1	300	2.1	0	0	0	0	0	0	300
1963	301	0.3	2.1	301	2.1	0	0	0	0	0	0	301
1964	295	0.3	2.0	295	2.0	0	0	0	0	0	0	295
1965	392	0.3	2.7	392	2.7	0	0	0	0	0	0	392
1966	828	0.6	5.7	828	5.7	0	0	0	0	0	0	828
1967	1,291	0.8	18.1	1,291	18.1	0	0	0	207	0.1	1.1	1,084
1968	1,729	1.0	24.3	1,587	22.5	142	1.8	2.0	1,500	0.9	8.0	229
1969	2,664	1.5	36.8	1,882	26.9	782	9.9	11.0	2,030	1.1	10.9	634
1970	3,300	1.7	45.8	2,344	33.7	956	12.1	13.4	3,556	1.8	13.9	− 256
1971	4,555	2.1	61.2	3,127	43.1	1,428	18.1	20.1	8,136	3.8	48.4	−3,581
1972	5,070	2.3	69.3	3,437	49.3	1,633	20.0	24.2	11,046	4.9	65.8	−5,976
1973	6,837	2.9	92.0	4,862	69.9	1,975	22.1	29.8	11,414	4.7	84.5	−4,577
1974	14,038	5.4	213.5	8,555	127.2	5,483	86.3	104.8 [3]	11,941	4.6	152.1	2,097
1975	19,332	6.7	451.3	11,291	267.0	8,041	184.3	233.1 [3]	12,412	4.4	182.1	6,920
1976	25,780	8.0	733.4	13,436	431.3	12,344	302.2	346.2 [3]	11,785	3.8	176.2	13,995

[1] Source: *Vneshnyaya torgovlya SSSR*, various issues.

[2] The USSR has been a net exporter of natural gas except in 1970-73 when imports from Iran and Afghanistan exceeded exports. Thereafter, deliveries under gas-for-pipe barter transactions with several West European countries and increased capacity of export pipelines restored the USSR to its position as a net exporter.

[3] Excluding Finland.

Table J-25

Natural Gas Trade, by Country [1]

Billion Cubic Meters

	1960	1965	1967	1970	1971	1972	1973	1974	1975	1970-75
Exports	0.24	0.39	1.30	3.30	4.56	5.07	6.84	14.04	19.33	53.14
Eastern Europe	0.24	0.39	1.30	2.34	3.13	3.44	4.86	8.56	11.29	33.62
Bulgaria	0	0	0	0	0	0	0	0.31	1.19	1.50
Czechoslovakia	0	0	0.27	1.34	1.64	1.94	2.36	3.23	3.69	14.20
East Germany	0	0	0	0	0	0	0.79	2.90	3.30	6.99
Hungary	0	0	0	0	0	0	0	0	0.60	0.60
Poland	0.24	0.39	1.03	1.00	1.49	1.50	1.71	2.12	2.51	10.33
Western Europe	0	0	0	0.96	1.43	1.63	1.98	5.49	8.04	19.52
Austria	0	0	0	0.96	1.43	1.63	1.62	2.11	1.88	9.63
Finland	0	0	0	0	0	0	0	0.44	0.72	1.16
Italy	0	0	0	0	0	0	0	0.79	2.34	3.13
West Germany	0	0	0	0	0	0	0.35	2.15	3.10	5.60
Imports	0	0	0.21	3.56	8.13	11.05	11.41	11.94	12.41	57.54
Afghanistan	0	0	0.21	2.59	2.51	2.85	2.74	2.85	2.85	16.39
Iran	0	0	0	0.97	5.62	8.20	8.68	9.09	9.56	41.15
Net Trade	**0.24**	**0.39**	**1.08**	**−0.26**	**−3.58**	**−5.98**	**−4.58**	**2.10**	**6.92**	**−4.40**

[1] Source: *Vneshnyaya torgovlya*, various issues.

Table J-26

USSR: Projected Trade in Natural Gas, by Country [1]

Billion Cubic Meters

		Projected					
	1976	1977	1978	1979	1980	1976-80	1985
Exports	**25.8**	**32.7**	**37.3**	**45.3**	**55.5**	**196.6**	**77.8**
Eastern Europe	13.4	16.0	17.5	24.0	30.6	101.5	43.1
Bulgaria	2.2	3.5	4.0	5.0	6.3	21.0	8.5
Czechoslovakia	4.3	4.5	5.0	5.5	6.3	25.6	10.0
East Germany	3.4	4.0	4.0	5.5	6.5	23.4	7.0
Hungary	1.0	1.0	1.0	2.5	4.0	9.5	5.4
Poland	2.5	3.0	3.5	4.5	6.0	19.5	8.1
Romania	0	0	0	1.0	1.5	2.5	2.1
Yugoslavia	0	0	0	0	0	0	2.0
Western Europe	12.4	16.7	19.8	21.3	24.9	95.1	34.7
Austria	2.8	2.8	2.8	2.8	2.8	14.0	4.0
Finland	0.9	0.9	1.0	1.0	1.4	5.2	1.0
France	1.0	1.5	2.0	2.0	4.7	11.2	7.7
Italy	3.7	6.5	7.0	7.0	7.0	31.2	7.0
West Germany	4.0	5.0	7.0	8.5	9.0	33.5	15.0
Imports	**11.8**	**12.9**	**12.9**	**13.0**	**14.6**	**65.2**	**31.0**
Afghanistan	2.5	2.9	2.9	3.0	4.0	15.3	4.0
Iran	9.3	10.0	10.0	10.0	10.6	49.9	27.0
Net Trade	**14.0**	**19.8**	**24.4**	**32.3**	**40.9**	**131.4**	**46.8**

[1] Actual for 1976. Source: *Vneshnyaya torgovlya SSSR 1976*, Moscow (1977). Trade estimates for the years 1977-80 and 1985 are based on (a) known Soviet–West Europe trade agreements; (b) for Eastern Europe, the trade arrangement under Orenburg pipeline agreement and assumed annual increments in gas deliveries to certain CEMA customers; (c) scheduled increases in imports from Iran under the "trilateral switch deal (see appendix G) and assumed slight increases in imports from Afghanistan.

Table J-27

Soviet Natural Gas Exports as a Percent of East European Gas Consumption

	Billion Cubic Meters		
	Consumption	Imports From the USSR	Soviet Imports as a Percent of Consumption
Bulgaria			
1965	0.07	0	0
1970	0.47	0	0
1975	1.19	1.19	100
Czechoslovakia			
1965	0.75	0	0
1970	2.08	1.34	64
1975	4.42	3.69	83
East Germany			
1965	0.15	0	0
1970	1.30	0	0
1975	11.30	3.30	29
Hungary			
1965	1.31	0	0
1970	3.67	0	0
1975	5.98	0.60	10
Poland			
1965	1.69	0.39	23
1970	5.98	1.00	17
1975	8.11	2.51	31
Romania			
1965	17.25	0	0
1970	24.83	0	0
1975	31.00	0	0
Total			
1965	**21.22**	0.39	**2**
1970	**38.33**	2.34	**6**
1975	**62.00**	11.29	**18**

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APPENDIX K

SOURCE REFERENCES

1. The following section is based on Iain F. Elliot, *The Soviet Energy Balance*, New York (1974), pp. 14-18, and Jeremy Russell, *Energy as a Factor in Soviet Foreign Policy*, Lexington, Mass. (1976), p. 59.
2. See the American Gas Association, *Gas Facts, 1976* (1977), p. 23 for recent US gas production data.
3. Most of the information in this paragraph is from Elliot, *Soviet Energy Balance*, pp. 14-18.
4. *Gazovaya promyshlennost'*, no. 8 (1977), p. 2.
5. R. D. Margulov et al., *Razvitiye gazovoy promyshlennosti i analiz techniko-ekonomicheskikh pokazateley*, VNIIZ Gazprom, Moscow (1976), p. 4.
6. S. A. Orudzhev, *Gazovaya promyshlennost' po puti progressa*, Moscow (1976), pp. 33-35.
7. Margulov, *Razvitiye gazovoy promyshlennosti*, p. 17.
8. *Agitator*, no. 15 (1976).
9. The following paragraph is based on Robert W. Campbell, *The Economics of Soviet Oil and Gas*, Baltimore (1968), p. 214, and Margulov, *Razvitiye gazovoy promyshlennosti*, p. 14.
10. Margulov, *Razvitiye gazovoy promyshlennosti*, p. 4.
11. *Ibid.*, p. 5, *Geologiya, bureniye i razrabotka gazovykh mestorozhdeniy*, no. 4 (1977), p. 3, and Orudzhev, *Gazovaya promyshlennost' p. 13.*
12. For an overview of this development, see A.D. Brentz et al., *Ekonomika gazodobyvayushchey promyshlennosti*, Moscow (1975), pp. 31-73; Margulov, *Razvitiye gazovoy promyshlennosti*, pp. 18-39; and Orudzhev, *Gazovaya promyshlennost'*, pp. 26-36.
13. Elliot, *Soviet Energy Balance*, p. 18.
14. Brentz, *Ekonomika*, p. 28, and Orudzhev, *Gazovaya promyshlennost'*, p. 12.
15. M. B. Ravich, *Gaz i ego primeneniye v narodnom khozyaistvye*, Moscow (1974), pp. 136-145.
16. *Gazovaya promyshlennost'*, no. 3 (1969), p. 5.
17. *Gazovaya promyshlennost'*, no. 11 (1976), p. 6; and *Pravda*, (26 February 1977), p. 2.
18. *Geologiya nefti i gaza*, no. 5 (1975), p. 8.
19. *Geologiya, bureniye i razrabotka gazovykh mestorozhdeniy*, no. 14 (1977), p. 17.

20. For an important, recent statement on exploration for oil and gas, see *Pravda* (10 August 1977), p. 2.
21. *Ekonomicheskaya gazeta*, no. 28 (1977), p. 17.
22. The following paragraph is based on *Review of Sino-Soviet Oil* (June 1975), p. 17; Joint Publications Research Service (JPRS) no. 63298, Translations on USSR Resources, no. 549 (29 October 1974), pp. 6-7; and Orudzhev, *Gazovaya promyshlennost'*, pp. 21-22.
23. *Review of Sino-Soviet Oil* (December 1970), p. 10.
24. *Ekonomicheskaya gazeta*, no. 6 (1977), p. 1.
25. See Brentz, *Ekonomika*, p. 28; Margulov, *Razvitiye gazovoy promyshlennosti*, pp. 29-32; and Orudzhev, *Gazovaya promyshlennost'*, p. 34.
26. *Pravda* (13 December 1976), p. 1.
27. *Ekonomicheskaya gazeta*, no. 6 (1977), p. 2.
28. *Turkmenskaya iskra* (19 February 1977), p.2.
29. *Gazovaya promyshlennost'*, no. 11 (1976), p.36. The Orenburg field produced 34.6 billion cu m in 1977 (*Gazovaya promyshlennost'*, no. 3 (1978), p. 2).
30. See the explanatory note on table 13 for the methodology used in deriving these cost figures.
31. Margulov, *Razvitiye gazovoy promyshlennosti*, p. 17.
32. Brentz, *Ekonomika*, p. 108.
33. Margulov, *Razvitiye gazovoy promyshlennosti*, pp. 23-25.
34. Orudzhev, *Gazovaya promyshlennost'*, p. 39; and JPRS no. 69777 (13 September 1977), p. 13.
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36. Brentz, *Ekonomika*, p. 110.
37. *Ekonomika gazovoy promyshlennosti*, no. 8 (1977), p. 5.
38. *Ibid.*, p. 4.
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40. *Vyshka* (September 1970), p. 2.
41. JPRS, no. 59271 (13 June 1973), p. 3.
42. *Gazovaya promyshlennost'*, no. 11 (1976), p. 9.
43. *Ekonomika gazovoy promyshlennosti*, no. 1 (1977), p. 13 and no. 7 (1976), p. 13.
44. Margulov, *Razvitiye gazovoy promyshlennosti*, p. 22.
45. *Ibid.*, p. 21.
46. *Ibid.*, p. 40.
47. *Ekonomika gazovoy promyshlennosti*, no. 8, (1977), p. 36.
48. *Ekonomicheskaya gazeta*, no. 6 (1977), p. 2.
49. Margulov, *Razvitiye gazovoy promyshlennosti*, p. 11.
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51. Margulov, *Razvitiye gazovoy promyshlennosti*, p. 18.
52. *Ibid.*, p. 40.
53. *Ibid.*, pp. 15 and 40.

54. Khaskin, *Osnovnyye fondy*, p. 45, and Margulov, *Razvitiye gazovoy promyshlennosti*, p. 15.
55. Orudzhev, *Ekonomika*, pp. 70-71.
56. *Review of Sino-Soviet Oil* (January 1972), p. 9, and *Gazovaya promyshlennost'*, no. 1 (1976), p. 2.
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58. *Oil and Gas Journal* (10 October 1977), p. 110.
59. *Izvestia* (12 December 1976), p. 2.
60. *Pravda* (4-5 May 1973) and *Gazovaya promyshlennost'*, no. 6 (1977), p. 32.
61. The data in this section are taken from *Vneshnyaya torgovlya SSSR*, Moscow, various issues.
62. *Ibid.*, for this section.
63. *Ibid.*
64. *Survey of World Broadcasts (SWB)*, EE/W925/A/11 (14 April 1977).
65. See, for example, *SWB*, SU/W901/A/12 (22 October 1976) and EE/W809/A/19 (9 January 1975); *Journal of Commerce* (16 January 1976), (4 September 1975), and (19 May 1976); *Izvestia* (10 June 1974); and *Vyshka*, (3 December 1975).
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70. See, for example, *Gazovaya promyshlennost'* no. 6 (1975), pp. 2-5, and no. 1 (1976), p. 3, and *Ekonomika gazovoy promyshlennosti*, no. 7 (1976), p. 7.
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78. *Gas Turbine World* (July 1976), p. 18.
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89. *Pravda* (7 March 1977). The Soviets have recently suggested that Urengoy might ultimately produce up to 200 billion to 250 billion cu m per year, but have not specified whether they truly intend to achieve this. See *Ekonomicheskaya gazeta*, no. 24 (June 1978), p. 2, for a discussion of Urengoy.
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92. Indications that the plenum did launch the drive can be found in *Sotsialisticheskaya industria* (31 December 1977) and *Literaturnaya gazeta* (11 and 18 January 1978).
93. A suggestion of this can be found in the *Pravda* editorial of 18 December 1977.
94. *Sotsialisticheskaya industria* (22 January 1978).
95. *Sotsialisticheskaya industria* (8 February and 3 March 1978). The Soviets are also discussing the start-up of construction of the second line before 1980. See *Pravda* (15 February 1978), pp. 1-2, for coverage of the problems facing the first pipeline's construction.
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97. See, for example, *Petroleum Economist* (April 1977), pp. 133-136.
98. *Gazovaya promyshlennost'*, no. 8 (1975), p. 5; Orudzhev, *Gazovaya promyshlennost'*, p. 39; and V. N. Kal'chenko, *Ekonomika gazovoy promyshlennosti*, Kiev (1974), p. 68.
99. *Neftyanaya i gazovaya promyshlennost'*, no. 4 (1975), p. 2.
100. *Ibid.*, p. 4.
101. Margulov, *Razvitiye gazovoy promyshlennosti*, p. 31.
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104. Margulov, *Razvitiye gazovoy promyshlennosti*, pp. 29-30, 32.
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108. *Neftyanaya i gazovaya promyshlennost'*, no. 1 (1977), p. 2.
109. For background on the Turkmen gas industry's development, see *Pravda* (4-5 May 1973) and (25 April 1975); *Stroitel'stvo truboprovodov*, no. 8 (August 1974), pp. 12-13; and *Geologiya, bureniye i razrabotka gazovykh mestorozhdeniy*, no. 8 (April 1977), pp. 7-11.

110. *SWB*, SU/W905/A/13 (19 November 1976).
111. Brentz, *Ekonomika*, p. 25.
112. *SWB*, SU/W922/A/10 (25 November 1977).
113. *SWB*, SU/W921/A/14 (18 March 1977).
114. *Turkmenskaya iskra* (19 February 1977), p. 2.
115. Based on *SWB*, SU/W917/A/7 (18 February 1977); SU/W911/A/7 (7 January 1977); and SU/W912/A/19 (14 January 1977); and JPRS, no. 68685 (25 February 1977), p. 6.
116. *Ekonomika gazovoy promyshlennosti*, no. 8 (1977), p. 36.
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118. Brentz, *Ekonomika*, p. 28.
119. Orudzhev, *Gazovaya promyshlennost'*, p. 12.
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121. *Review of Sino-Soviet Oil* (August 1975), p. 13.
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124. *Ekonomicheskaya gazeta*, no. 24 (June 1978), p. 1.
125. *Gazovaya promyshlennost'*, no. 4 (1977), p. 7.
126. *Gazovaya promyshlennost'*, no. 8 (1977), p. 6, and *Geologiya nefti i gaza*, no. 1 (1976), pp. 1-2.
127. For an overview of costs and capital investment in West Siberian gas development, see *Izvestia sibirskogo otdeleniya akademii nauk SSSR. Seriya obshchestvennykh nauk*, no. 11 (September 1977), pp. 116-119.
128. *Ekonomika gazovoy promyshlennosti*, no. 2 (1975), p. 12.
129. *Gazovaya promyshlennost'*, no. 3 (1976), p. 14.
130. *Ekonomika gazovoy promyshlennosti*, no. 2 (1975), p. 12.
131. Khaskin, *Osnovnyye fondy*, p. 54.
132. *Gazovaya promyshlennost'*, no. 3 (1976), pp. 12-13.
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135. *Ibid.*, p. 7.
136. *Pravda* (27 February 1977), p. 3.
137. *Gazovaya promyshlennost'*, no. 3 (1976), p. 14.
138. *Ibid.*, p. 12.
139. *Ekonomika gazovoy promyshlennosti*, no. 2 (1975), p. 12.
140. *Stroitel'stvo truboprovodov*, no. 1 (1976), pp. 10-13.
141. Khaskin, *Osnovnyye fondy*, p. 55.
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143. *Sovetskaya rossiya* (4 December 1976), p. 2.
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145. *Gazovaya promyshlennost'*, no. 4 (1977), p. 6.
146. *Gazovaya promyshlennost'*, no. 3 (1977), p. 6.
147. *Ekonomicheskaya gazeta*, no. 9 (February 1978), p. 2.
148. Orudzhev, *Gazovaya promyshlennost'*, p. 21.

149. *Stroitel'stvo truboprovodov*, no. 8 (1976), p. 20.
150. *Review of Sino-Soviet Oil* (May 1975), p. 23.
151. *Review of Sino-Soviet Oil* (February 1975), p. 17.
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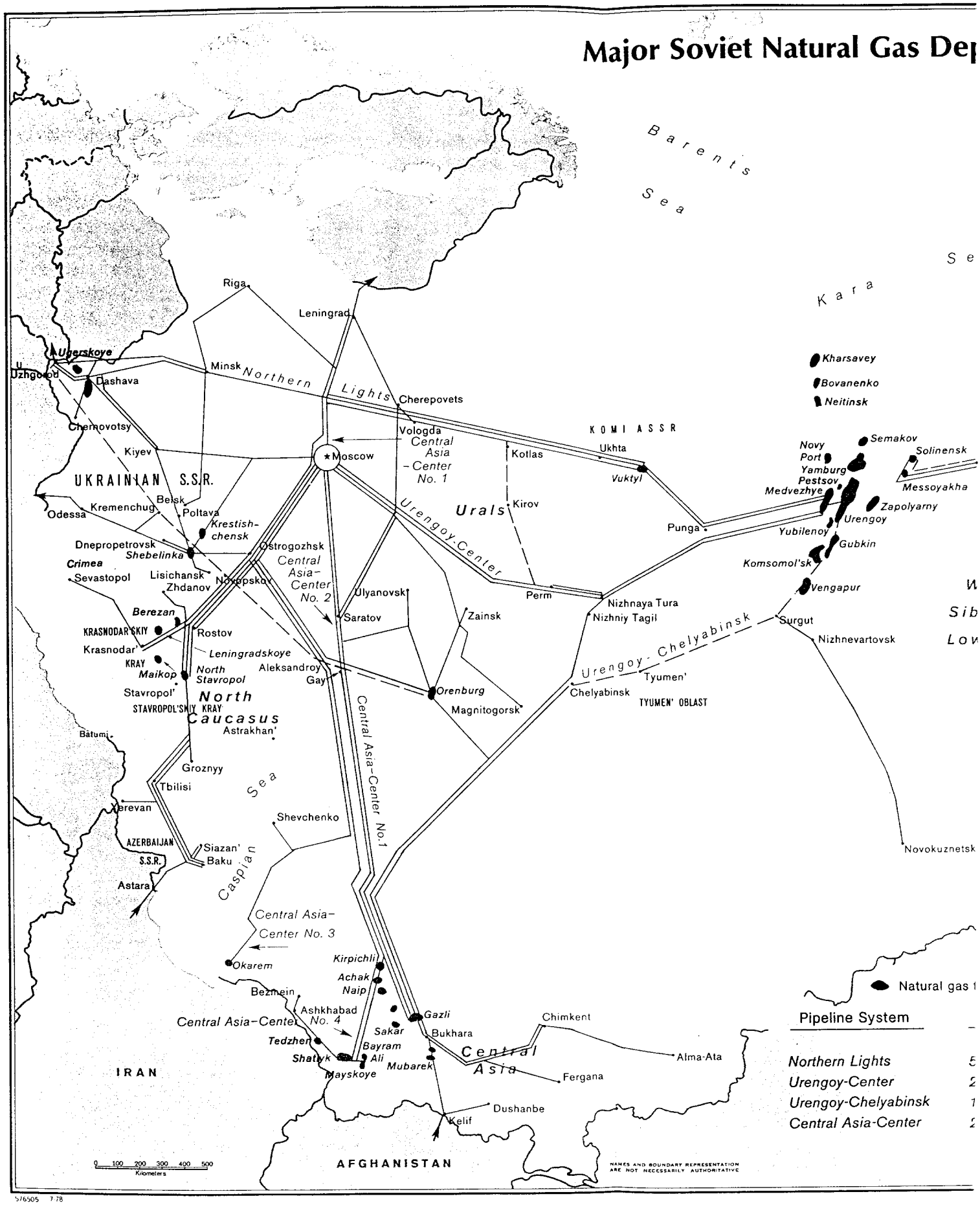
154. *SWB*, SU/W915/A/6 (4 February 1975).
155. *Oil and Gas Journal* (6 June 1977), p. 71.
156. *Ekonomika gazovoy promyshlennosti*, no. 8 (1975), p. 26.
157. *Turkmenskaya iskra* (28 December 1976), p. 2.
158. *Gazovaya promyshlennost'*, no. 5 (1976), p. 33.
159. *Gazovaya promyshlennost'*, no. 4 (1977), p. 5.
160. *Ibid.*
161. Orudzhev, *Gazovaya promyshlennost'*, pp. 70-71.
162. Mention of this Soviet practice is made in *Pipeline and Gas Journal* (November 1976), p 36.
163. *Izvestia* (28 September 1976), p. 5.
164. *Ibid.*
165. *Gazovaya promyshlennost'*, no. 7 (1976), p. 13.
166. *Pravda Ukrainy* (19 November 1976), p. 2.
167. For general details on the project, noted in the following paragraphs, see *Ekonomicheskaya gazeta*, no. 39 (1975), p. 24; *Pravda* (1 November 1975), p. 4; *Izvestia* (24 February 1976), p. 4; JPRS, no. 68085 (19 October 1976), pp. 12-20; and *Ekonomika stroitel'stva*, no. 11 (November 1977), pp. 33-38.
168. *Ekonomicheskaya gazeta*, no. 39 (1975), p. 21.
169. See, for example, *Oil and Gas Journal* (3 February 1975), p. 60.
170. *European Chemical News* (20-27 August 1976), p. 14.
171. JPRS, no. 68085 (19 October 1976), p. 18.
172. FBIS, "Soviet Union" (7 July 1975), p. D-5.
173. JPRS, no. 68085 (19 October 1975), p. 20.
174. *Ibid.*; FBIS, "Soviet Union" (19 September 1975), p. D-1; and JPRS, no. 65453 (13 August 1975), pp. 1-2.
175. For basic data see *New York Times* (1 December 1975); *Literaturnaya gazeta* (17 December 1975), p. 9; *Petroleum Intelligence Weekly* (22 November 1976), p. 4; and *Ekonomicheskaya gazeta* (6 February 1976), p. 8.
176. *Literaturnaya gazeta* (17 December 1975), p. 9.
177. *Journal of Commerce* (4 June 1976).
178. *Oil and Gas Journal* (6 December 1976), p. 58.
179. *East-West Trade* (25 July 1977), p. 3.
180. *Ibid.*
181. *Ibid.*
182. *East-West Trade News* (31 May 1978) p. 2.
183. *Reuter* (27 March 1977).

184. At a meeting in Tokyo in May 1978, the three countries did sign an agreement continuing the initial exploratory phase and tentatively agreeing to begin the development phase if sufficient reserves are proved. See *Journal of Commerce* (30 May 1978), p. 32.
185. *East-West Trade* (25 July 1977), p. 3.
186. *New York Times* (30 June 1973), p. 43.
187. *Oil and Gas Journal*, "Newsletter" (30 May 1977).
188. *Financial Times* (28 April 1976).
189. Moscow Narodnyy Bank, *Press Bulletin* (28 April 1976), p. 6.
190. *Oil and Gas Journal*, "Newsletter" (30 May 1977).


Major Soviet Natural Gas Dep
Barents Sea
Kara Se
Riga
Leningrad
Uzhgorod
Uzherskoye
Dashava
Minsk
Northern Lights
Cherepovets
Chernovtsy
Vologda
Central Asia - Center No. 1
KOMI ASSR
Ukhta
Kharsavey
Bovanenko
Neitinsk
Kiyev
Moscow
Kotlas
Vuktyl
Semakov
Novy Port
Yamburg
Pestsov
Medvezhye
Solinensk
Messoyakha
Zapolyarny
Urengoy
Yubileinoy
Gubkin
Komsomol'sk
Vengapur
UKRAINIAN S.S.R.
Urals
Kirov
Urengoy-Center
Punga
Odessa
Kremenchug
Belsk
Poltava
Krestishchensk
Dnepropetrovsk
Shebelinka
Ostrogozhsk
Crimea
Sevastopol
Lisichansk
Zhdanov
Novopskov
Central Asia-Center No. 2
Ulyanovsk
Perm
Nizhnaya Tura
Nizhniy Tagil
Surgut
Nizhnevartovsk
Berezan
KRASNODAR SKIY KRAY
Krasnodar'
Rostov
Saratov
Zainsk
Leningradskoye
Maikop
North Stavropol
Aleksandroy Gay
Urengoy-Chelyabinsk
Tyumen'
Chelyabinsk
TYUMEN' OBLAST
Orenburg
Magnitogorsk
Stavropol'
STAVROPOL'SKIY KRAY
North Caucasus
Astrakhan'
Batumi
Groznyy
Tbilisi
Sea
Yerevan
Shevchenko
Central Asia-Center No.1
AZERBAIJAN S.S.R.
Siazan'
Baku
Caspian
Astara
Novokuznetsk
Central Asia-Center No. 3
Okarem
Kirpichli
Achak
Naip
Bezmein
Ashkhabad
Central Asia-Center No. 4
Gazli
Chimkent
Sakar
Bukhara
Tedzhen
Bayram Ali
Shatlyk
Mayskoye
Mubarek
Central Asia
Alma-Ata
Fergana
IRAN
Dushanbe
Kelif
AFGHANISTAN
Natural gas
Pipeline System
Northern Lights 5
Urengoy-Center 2
Urengoy-Chelyabinsk 1
Central Asia-Center 2
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Kilometers
NAMES AND BOUNDARY REPRESENTATION ARE NOT NECESSARILY AUTHORITATIVE
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